ASTRONOMY

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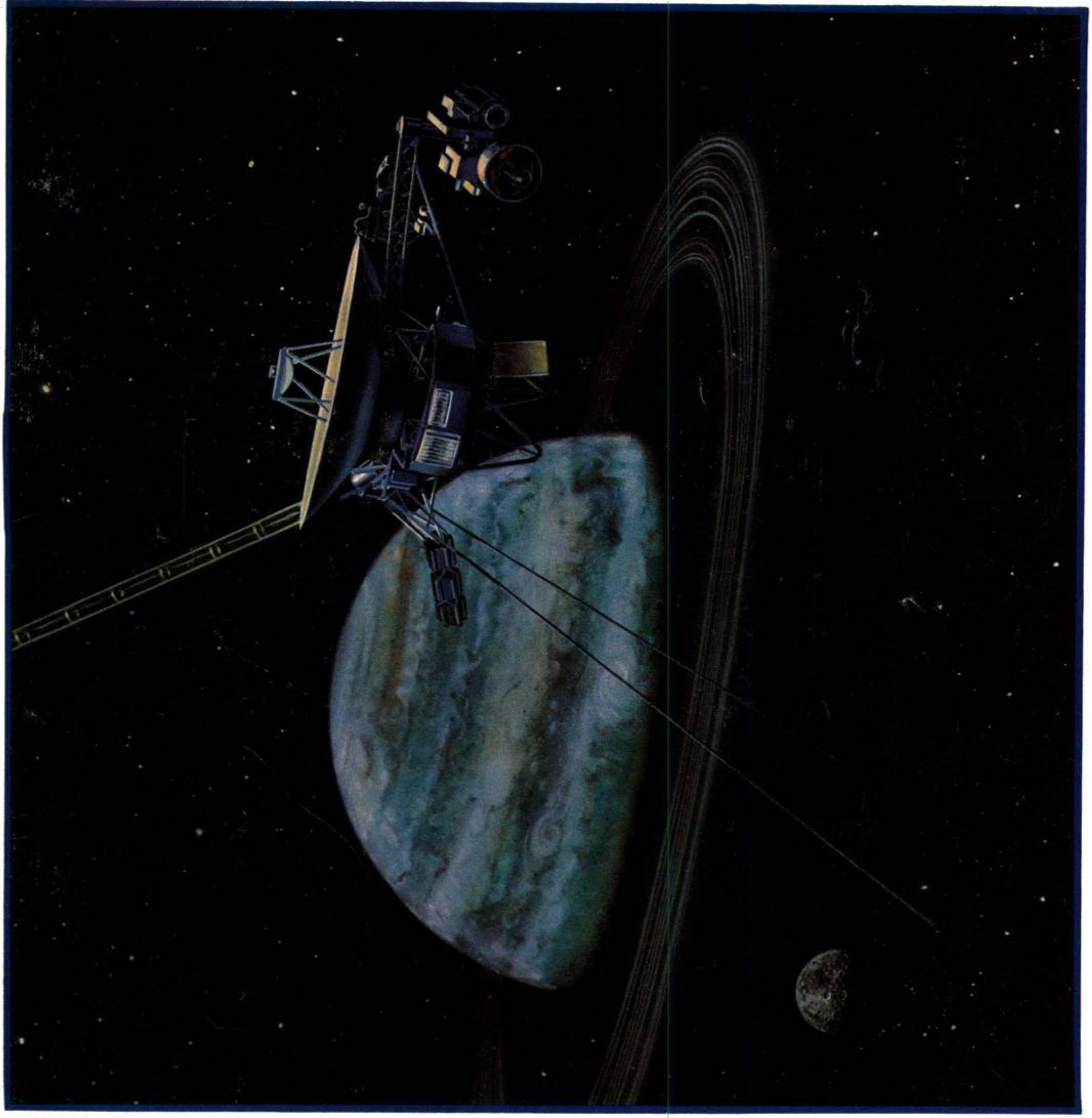

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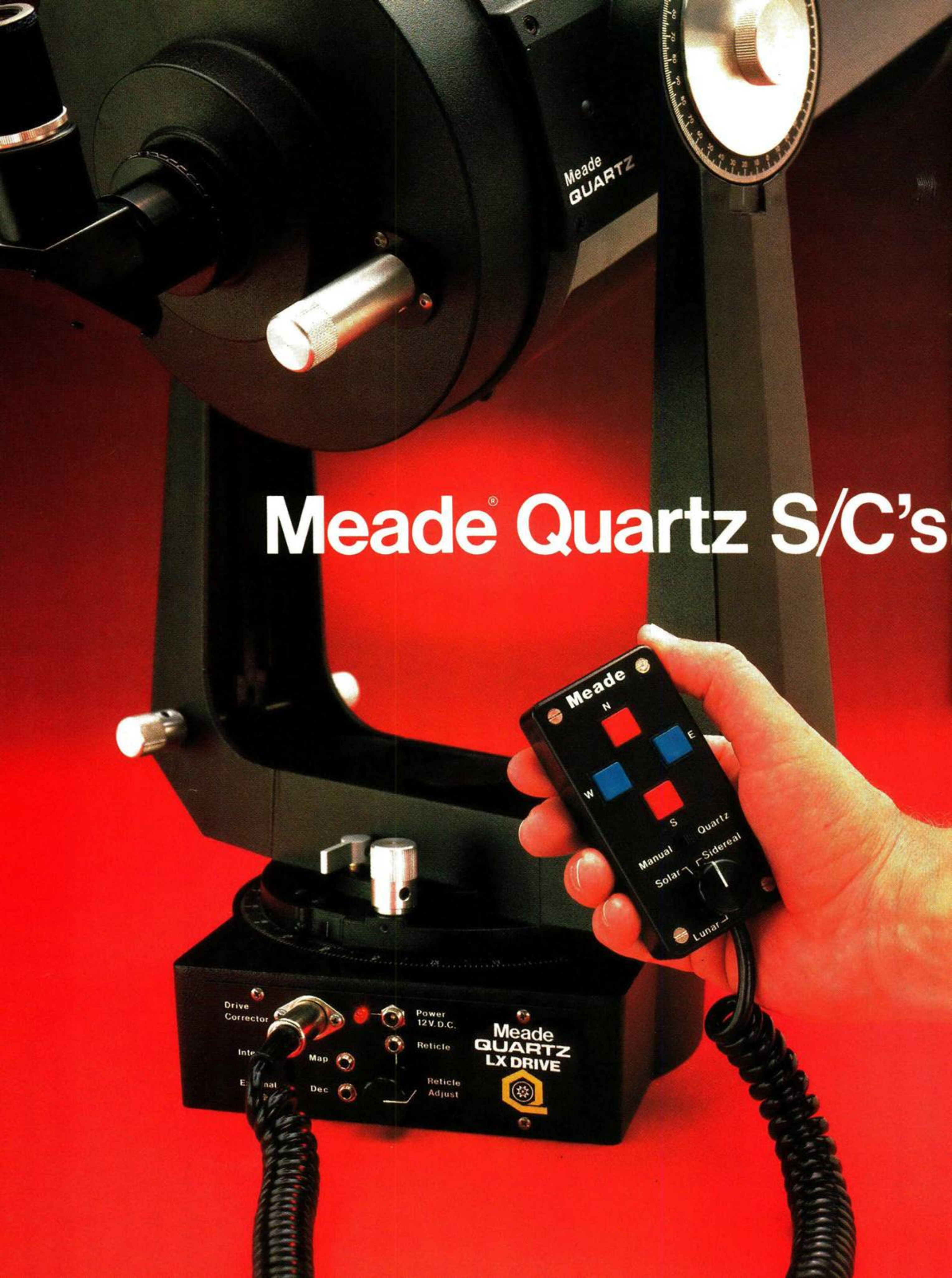
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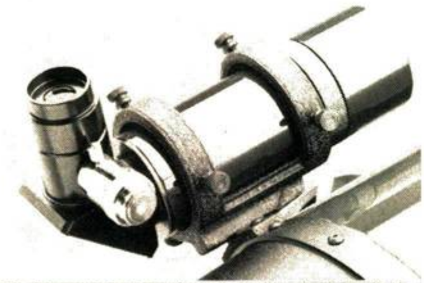

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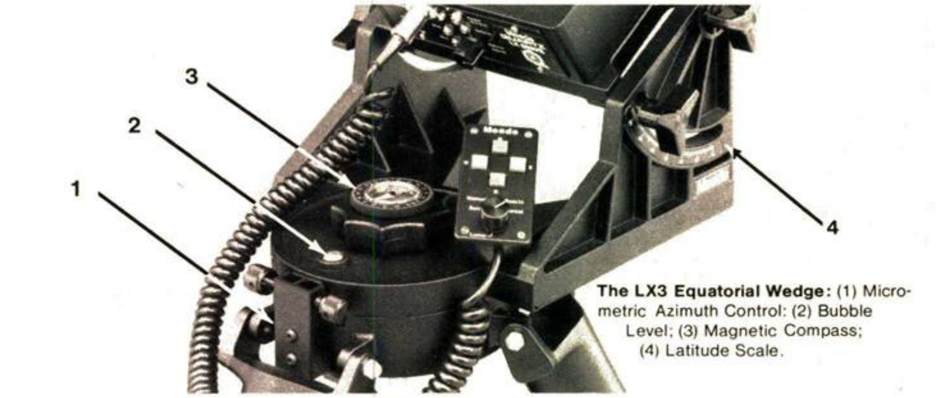

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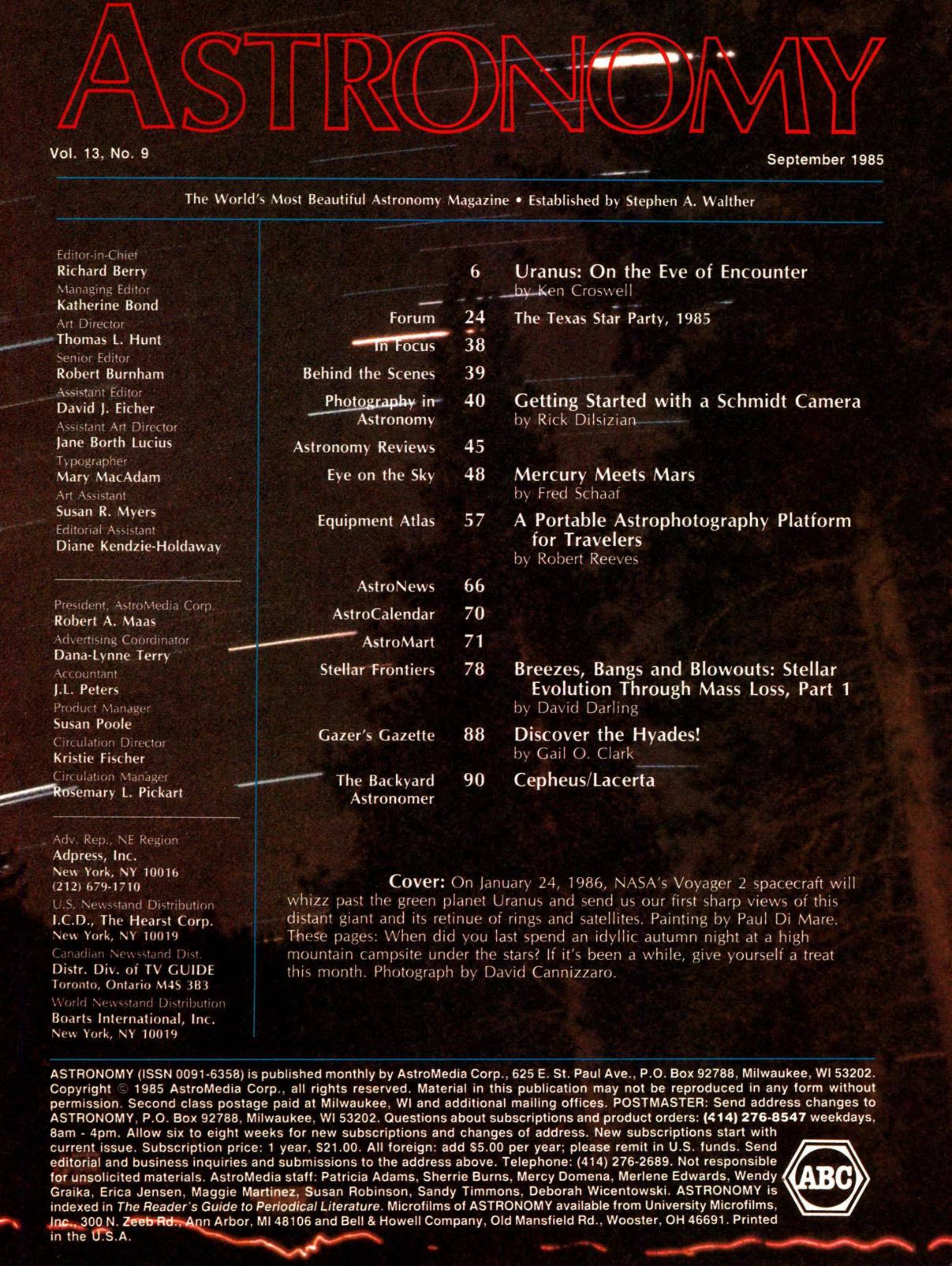

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Cover: On January 24, 1986, NASA's Voyager 2 spacecraft will whizz past the green planet Uranus and send us our first sharp views of this distant giant and its retinue of rings and satellites. Painting by Paul Di Mare. These pages: When did you last spend an idyllic autumn night at a high mountain campsite under the stars? If it's been a while, give yourself a treat this month. Photograph by David Cannizzaro.

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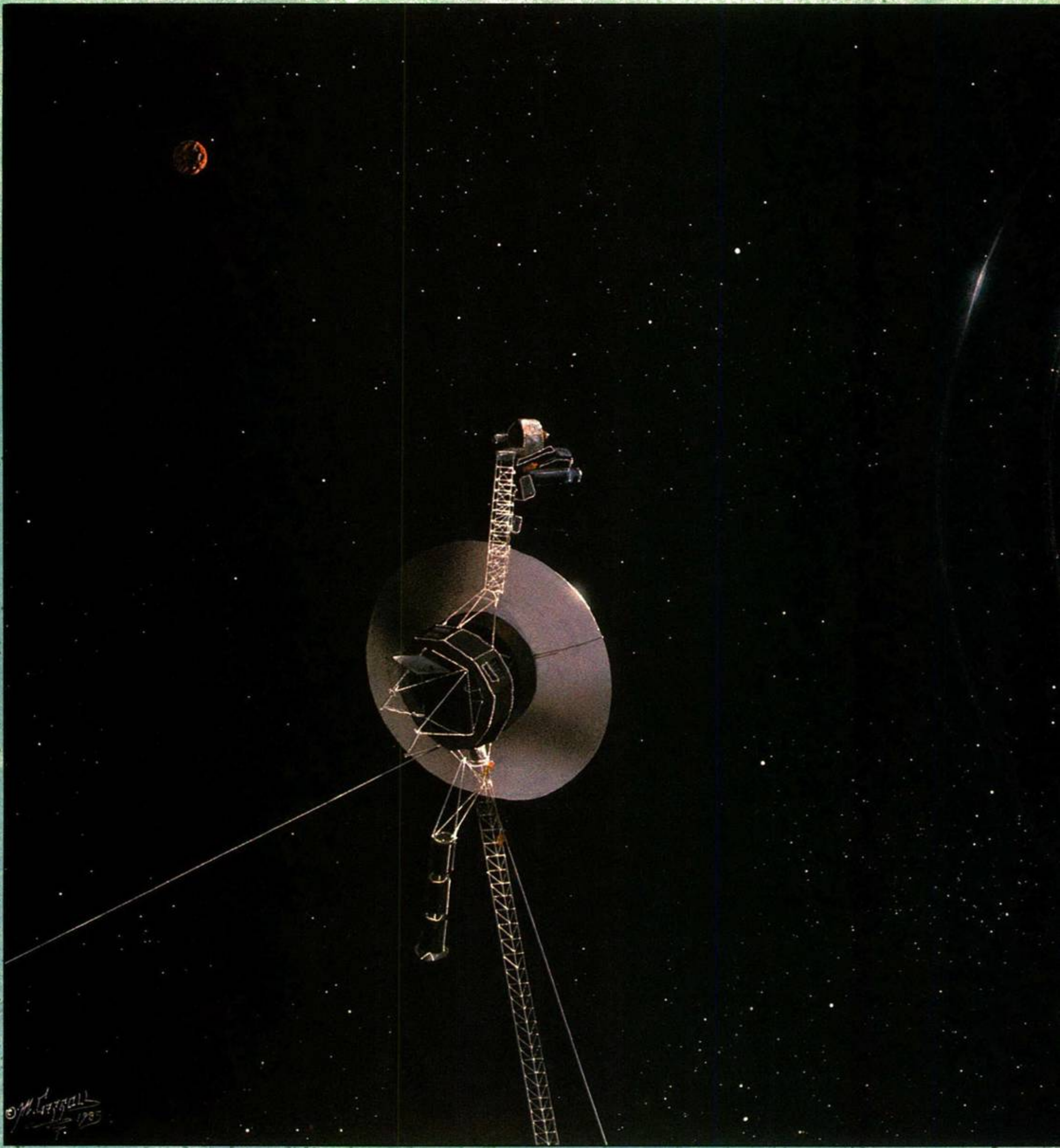

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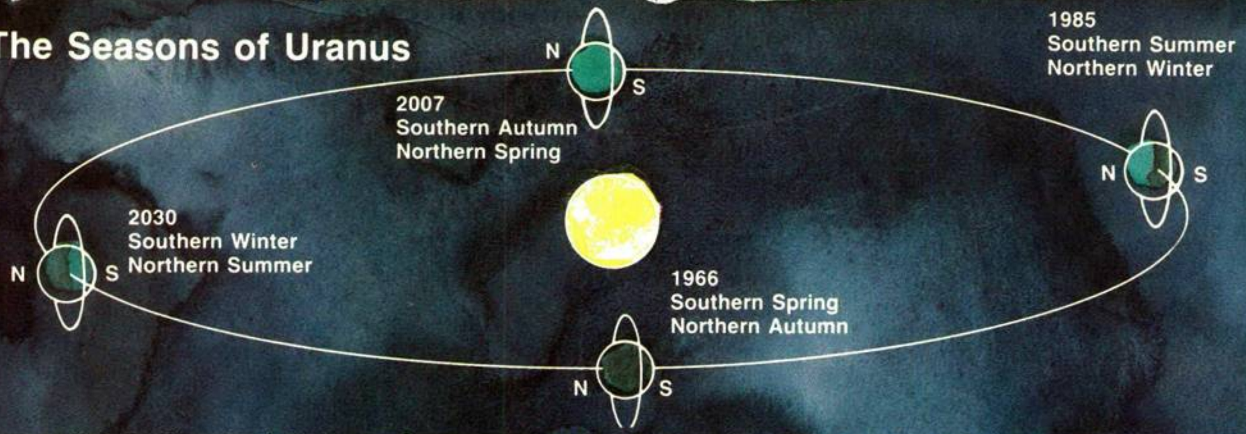
Uranus:

On the Eve of the Encounter

by Ken Croswell

The Seasons of Uranus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Because its axis of rotation is inclined 98° to the plane of the ecliptic, Uranus "lies on its side" in space and its seasons are unlike those of the other planets. It is now summer in the southern hemisphere, and the south pole lies in continuous sunlight while the north pole is exposed to constant darkness. The reason each season does not last exactly 21 years is that Uranus' orbit is somewhat eccentric: when it is farther from the Sun, Uranus travels more slowly and its seasons last longer; when it is nearer the Sun, Uranus travels faster and the seasons are shorter.

Uranus Data

Distance from Sun	**19.1819 Astronomical Units**
Diameter	**52,300 km**
Year	**84.0139 years**
Day	**15 to 17 hours**
Number of known moons	**5**
Axial tilt	**97.92°**
Temperature	**58 K**
Apparent visual magnitude	**5.5 (maximum)**
Color	**green**
Mass	**14.54 Earth masses**
Density	**1.2 gm/cm²**
Oblateness	**0.02**
Albedo	**40% to 50%**
Orbital eccentricity	**0.0472**
Orbital inclination	**0.77°**
Orbital speed	**6.81 km/sec**
Escape velocity	**21 km/sec**
Number of known rings	**9**
Planet discovered by	**William Herschel: March 13, 1781**
Named by	**Johann Bode**

Within a very few months, we will gaze on a world more distant than any we have yet explored — a world which lies twice as far from the Sun as Saturn. No humans will be there; in their stead is the robot spacecraft Voyager 2, equipped with cameras and sensitive instruments. This distant planet is Uranus; Voyager's reconnaissance of this remote world will mark our entrance into a new and different realm of the solar system.

The intrepid explorer, Voyager 2, is now in its ninth year of interplanetary travel. It left Earth in August 1977, traversed the asteroid belt, and successfully encountered Jupiter in July 1979 and Saturn in August 1981. Each day the spacecraft draws more than a million kilometers closer to Uranus; it will pass closest to the mysterious planet next January 24th. Now, on the eve of this exciting encounter, let's examine what we know about Uranus and how Voyager 2 will help us learn more.

As anyone who has seen it in a backyard telescope will testify, Uranus is a green planet. It's green because its hydrogen-helium atmosphere contains methane gas which absorbs red light. It is also a very cold planet with an effective temperature only 58 Kelvins above absolute zero. Astronomers do not know for sure how long a day on Uranus lasts, but they do know that the axis about which Uranus spins is tilted 98° from the plane of its orbit — unique among the major planets of the solar system. Circling Uranus are five small moons and nine dark rings.

Uranus orbits our star once every 84 years at a distance from the Sun 19 times that of Earth. Although Uranus and its twin planet Neptune are gas giants like Jupiter and Saturn, they are much smaller and have different structures as well. At 52,300 kilometers in diameter, Uranus is intermediate in size between Jupiter and Earth.

The Discovery of Uranus

Uranus is unique among the naked eye planets: it had to be discovered. No one recognized the wanderings of this fifth-magnitude object until 1781, and its unexpected discovery was not the work of a professional astronomer manning a well-equipped observatory, but that of an amateur astronomer armed with a homemade telescope.

The amateur was William Herschel. While systematically searching the sky for double stars (which made him nearly unique in his time, since most astronomers then studied the solar system and neglected the stars beyond), Herschel made one of the greatest solar system discoveries ever.

On March 13, 1781, while working his way through the stars in the constellation Gemini, Herschel noticed an object which did not look like a star. He increased his telescope's magnification and found that the object's size increased, unlike stars which remain points of light under higher magnification. Herschel suspected he had discovered a comet. Four nights later, Herschel confirmed the hypothesis: the new object was a comet, for it had moved.

After hearing news of the discovery, scientists endeavored to compute the comet's orbit. In order to do so, they assumed it had a typical comet's orbit — that its closest point to the Sun did not lie far from Earth's orbit.

But the "comet" did not follow their predictions. Several weeks after the discovery, Nevil Maskelyne pointed out the motion was consistent with that of a planet orbiting the Sun far from Earth. Months later, it became clear that Herschel's discovery was not a comet; it was, in fact, a planet.

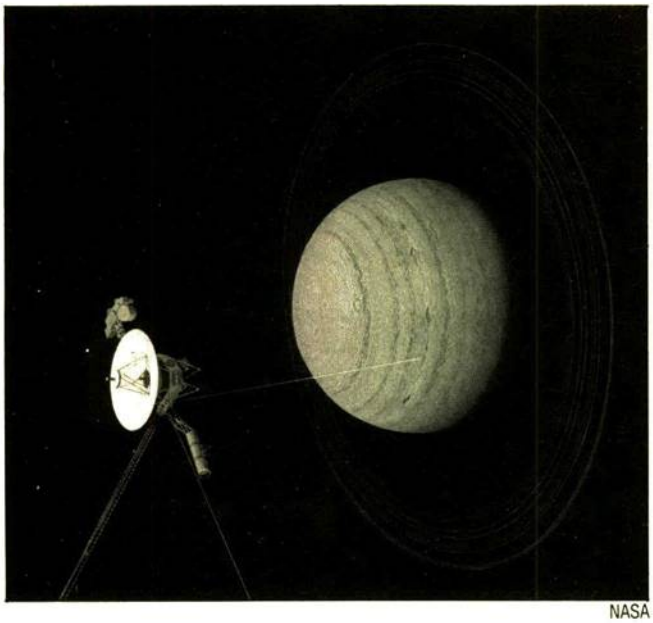
While the discovery of Uranus brought fame to this English amateur astronomer, it brought vindication to a German professional astronomer: Johann Bode. Bode first suggested the name "Uranus" for the new planet, but, more importantly, he strongly advocated a principle formulated by Johann Daniel Titius in 1766. According to Titius, the distances of the then-known planets follow an interesting sequence. It starts with the numerical sequence 0, 3, 6, 12, 24, 48 . . . , where each number but the first and second is double its predecessor. Add 4 to each number to obtain 4, 7, 10, 16, 28, 52 . . . , then divide each number by 10. On a scale where the Earth's distance is taken as 1, the sequence approximates the distances of the other planets:

Planet	Bode's Law	Actual Distance (Astronomical Units)
Mercury	0.4	0.387
Venus	0.7	0.723
Earth	1.0	1.000
Mars	1.6	1.524
?	2.8	—
Jupiter	5.2	5.203
Saturn	10.0	9.539

This became known as Bode's Law or, less commonly but more correctly, the Titius-Bode Law. Scientific laws are sometimes named not after their discoverers, but after their most enthusiastic supporters — and Bode was very enthusiastic about this one. In his papers on astronomy and as editor of a prestigious German astronomical journal, he constantly argued in favor of the law's validity. But most astronomers regarded the sequence as an odd coincidence. Bode focused on the mysterious gap between Mars and Jupiter and predicted the presence of a planet there, but the notion of a still undiscovered planet so close to Earth struck most astronomers as absurd. One beyond Saturn never occurred to them.

But Uranus fit Bode's Law almost perfectly: the law predicted a distance of 19.6 AUs for Uranus; Uranus lies at 19.18 AUs from the Sun. The discovery of Uranus and its seeming confirmation of Bode's Law emboldened Bode, and many astronomers swung to his side.

On September 21, 1800, Bode and five other



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astronomers gathered at a house in Lilienthal, Germany. Their premise: a planet lies between Mars and Jupiter. Their goal: develop a plan to discover the planet. They ultimately agreed that the best strategy was to divide the zodiac into 24 separate regions, each to be monitored by a different astronomer.

One individual they planned to invite on the search was Sicilian astronomer Giuseppe Piazzi. But on January 1, 1801 — before he even learned of the others' plans — Piazzi found what they were looking for: the first asteroid, Ceres, orbiting the Sun between Mars and Jupiter. In 1802, one of the five who gathered with Bode — Heinrich Olbers — discovered Pallas; in 1804 came Juno; and in 1807, Vesta. In 1830, after 23 years went by with no further discoveries, Friedrich Bessel suggested constructing improved star maps of the zodiac to help asteroid hunters.

Unknown to Bessel, these charts would aid in a far greater discovery. The irregularities in Uranus' motion across the sky led some astronomers to suspect that a planet lay beyond Uranus — even farther from the Sun — and was pulling Uranus ahead or behind through the force of its gravity. The English astronomer John Couch Adams analyzed the irregularities of Uranus' motion and predicted the location of a planet beyond Uranus in 1845, but he could not convince English astronomers to look for it until 1846. When they finally did, astronomers searched the entire zodiac rather than looking where Adams had predicted the planet would be.

In 1846, French astronomer Urbain Leverrier independently predicted the location of the planet, but he had no luck convincing his countrymen to look for it either. So in September 1846, he informed German astronomer Johann Galle of the planet's predicted position. Galle and a visiting student, Heinrich d'Arrest, pointed the telescope to the indicated region of the sky but saw nothing planet-like. Using the star chart that had been prepared for asteroid hunters, they compared the objects they saw with the stars on the map. Minutes later, they discovered Neptune.

Although William Herschel was the first to recognize Uranus, he was not the first to see it. Following the realization that Herschel's "comet" lay far beyond Saturn, astronomers knew they would need observations over long periods of time to compute an accurate orbit, since Uranus takes so long to orbit the Sun. But Uranus is a fifth-magnitude object, visible to the naked eye. Bode suggested that astronomers might have observed Uranus in the past, but mistaken it for a star. If these observations existed, they would help astronomers compute Uranus' orbit.

Bode was right. If you look at the constellation Taurus on a good star map, you will find a star marked 33 Tauri and another named 35 Tauri; there is no 34 Tauri. That star was, in fact, Uranus. Flamsteed catalogued it on December 23, 1690 — more than 90 years before Herschel actually discovered the planet. At least three other astronomers also observed Uranus prior to its discovery, but all of them thought it was a star.

The Planet Uranus

Despite valiant efforts to learn more about Uranus and Neptune, astronomers have remained almost totally ignorant of their true natures. While spacecraft have landed on Venus and Mars, scientists wishing to study Uranus and Neptune must conduct their investigations from this planet. From Earth, distant Uranus appears smaller than Jupiter's Great Red Spot and Neptune looks smaller still. It is hardly surprising that even such basic data as rotation periods are still poorly known for these worlds.

Yet Uranus and Neptune are very important planets, for they take us into a new region of the solar system. Each planet in the solar system represents a sample of the conditions in the primitive nebula where it formed. The primitive solar nebula in the inner solar system was hot, so only substances with high melting temperatures — silicate minerals and iron — could condense there. In the outer solar system, though, temperatures were so low that ices of water, methane, and ammonia condensed and became constituents of these worlds. Furthermore, the outer planets had enough mass to attract the light gases hydrogen and helium, which were very abundant in the primitive nebula.

For this reason, the eight known planets of the solar system divide into two distinct groups. The four inner planets — Mercury, Venus, Earth, and Mars — are small, dense worlds of rock and iron with low-mass atmospheres surrounding them. Beyond the asteroid belt lie the four outer planets, the gas giants: Jupiter, Saturn, Uranus, and Neptune. These are high-mass, low-density worlds with extremely massive atmospheres of hydrogen and helium.

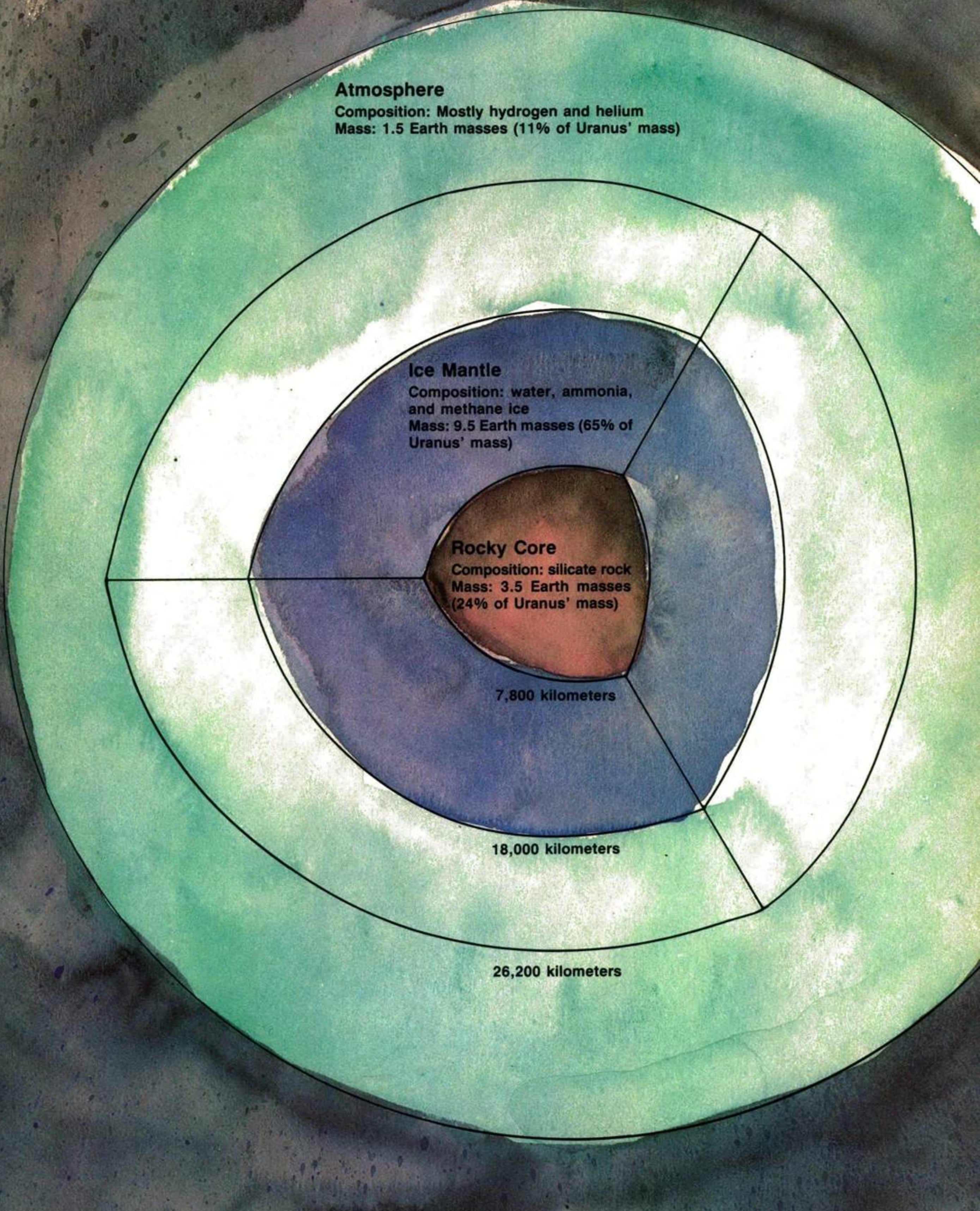
If we look more closely at the giant planets, we see that these four planets also constitute two groups. Jupiter and Saturn form one group; Uranus and Neptune form the other. Jupiter and Saturn are far more massive than Uranus and Neptune: Jupiter's mass is 318 times that of Earth's and Saturn's is 95 times greater. Uranus, by contrast, is only 15 times more massive whereas Neptune is 17 times larger.

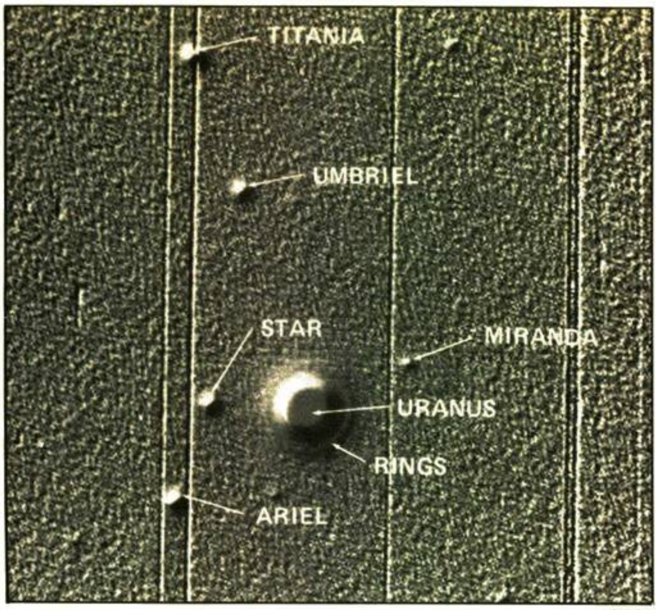
Yet scientists believe all four giant planets have rock-ice cores containing between 10 to 20 Earth masses. This similarity points to their greatest difference: the cores of Jupiter and Saturn are far less massive than their thick atmospheres. For Uranus and Neptune, however, the opposite holds true: the rock and ice are more massive than the hydrogen atmosphere, which merely forms a deep envelope about them.

What exactly is Uranus' structure? Astronomers really don't know because the fundamental data are so uncertain. In order to construct a model of a planet's

A Model of Uranus' Interior

In this model of Uranus, the rocky core amounts to just under one-fourth of the total mass; it is enveloped in a thick layer of frozen water, ammonia, and methane with nearly three times its mass. The remaining 11% of the planet's mass is the hydrogen/helium atmosphere. Based on a model by Hubbard and MacFarlane published in the *Journal of Geophysical Research*, 85: 225 (1980).


Atmosphere
Composition: Mostly hydrogen and helium
Mass: 1.5 Earth masses (11% of Uranus' mass)
Ice Mantle
Composition: water, ammonia, and methane ice
Mass: 9.5 Earth masses (65% of Uranus' mass)
Rocky Core
Composition: silicate rock
Mass: 3.5 Earth masses (24% of Uranus' mass)
7,800 kilometers
18,000 kilometers
26,200 kilometers



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interior, astronomers must know its mass — which is accurately known for Uranus from the orbits of the planet's satellites. Another necessary datum is the planet's density — mass divided by volume — which requires knowledge of both the mass and diameter. Because it is far away, the angular size of Uranus is small and therefore hard to measure precisely. Although we know its diameter is about 52,300 kilometers, there is some uncertainty about this figure. Together, these data yield a somewhat uncertain density of 1.2 grams per cubic centimeter for Uranus. The Earth, in contrast, has a density of 5.52 grams per cubic centimeter.

Although a planet's mass and density are prerequisites for constructing a model, scientists also require the planet's oblateness, gravitational field, and rotation period. Oblateness measures how pumpkin-shaped a planet is; a perfect sphere has zero oblateness. A planet's rotation flattens it somewhat and Uranus' oblateness is an uncertain 2%. The rings of Uranus have provided accurate information on the planet's gravitational field, however.

In order for this data to be really useful, though, we must also know the planet's rotation period. Look in nearly any but the most recent astronomy textbooks and you will find, in a table of data for the planets, that the length of a day on Uranus is 10.8 hours, and on Neptune it is 15.8 hours. This all sounds very nice, but just where did those numbers come from? Were these recently obtained data? No — in fact, they date back to 1930 and work done by J.H. Moore and D.H. Menzel. We now know their calculations were incorrect.

Paradoxically, this made scientists trying to model Uranus very happy. They found that, for the generally accepted rotation period, realistic models for Uranus turned out too oblate. Today scientists believe Uranus' day is longer — between 15 and 17 hours — although there are reports that it may be longer than 24 hours. In any case, Voyager 2 should nail down Uranus' rotation period once and for all.

Although they must work with large uncertainties in quantities they take for granted with other planets, astronomers believe they have a rough idea of Uranus' interior structure. One model, developed by William Hubbard and J.J. MacFarlane in 1980, proposes that the central part of Uranus consists of a rocky core three to four times the Earth's mass. Surrounding the core is a massive mantle (9 to 10 Earth masses) composed of water ice, ammonia ice, and methane ice. Above the mantle lies a hydrogen-helium atmosphere.

More recent studies suggest this model is too condensed toward the center. One way to lessen the central condensation of the model is to increase the ice-to-rock ratio, since ice is lighter than rock. Another method is to transfer some of the methane ice to the hydrogen-helium atmosphere as gas, since a methane molecule (CH_4) is eight times heavier than a hydrogen molecule (H_2). Atmospheric methane explains, in fact, why Uranus is green. Through a telescope, Uranus looks like a little green pea suspended against the heavens. Methane absorbs sunlight in the red and infrared, so the light that makes its way back to our eyes appears greenish.

Such absorptions tell astronomers a great deal about the composition of the planet's atmosphere. By analyzing which characteristic "signature" wavelengths are absent in sunlight reflected from a planet, astronomical spectroscopists can determine whether absorbing gases, like methane, are present. Other gases which do not absorb light may also be present, but we cannot detect them directly, so astronomers must computer-model their abundances using a mixture of theory and inspired guesswork.

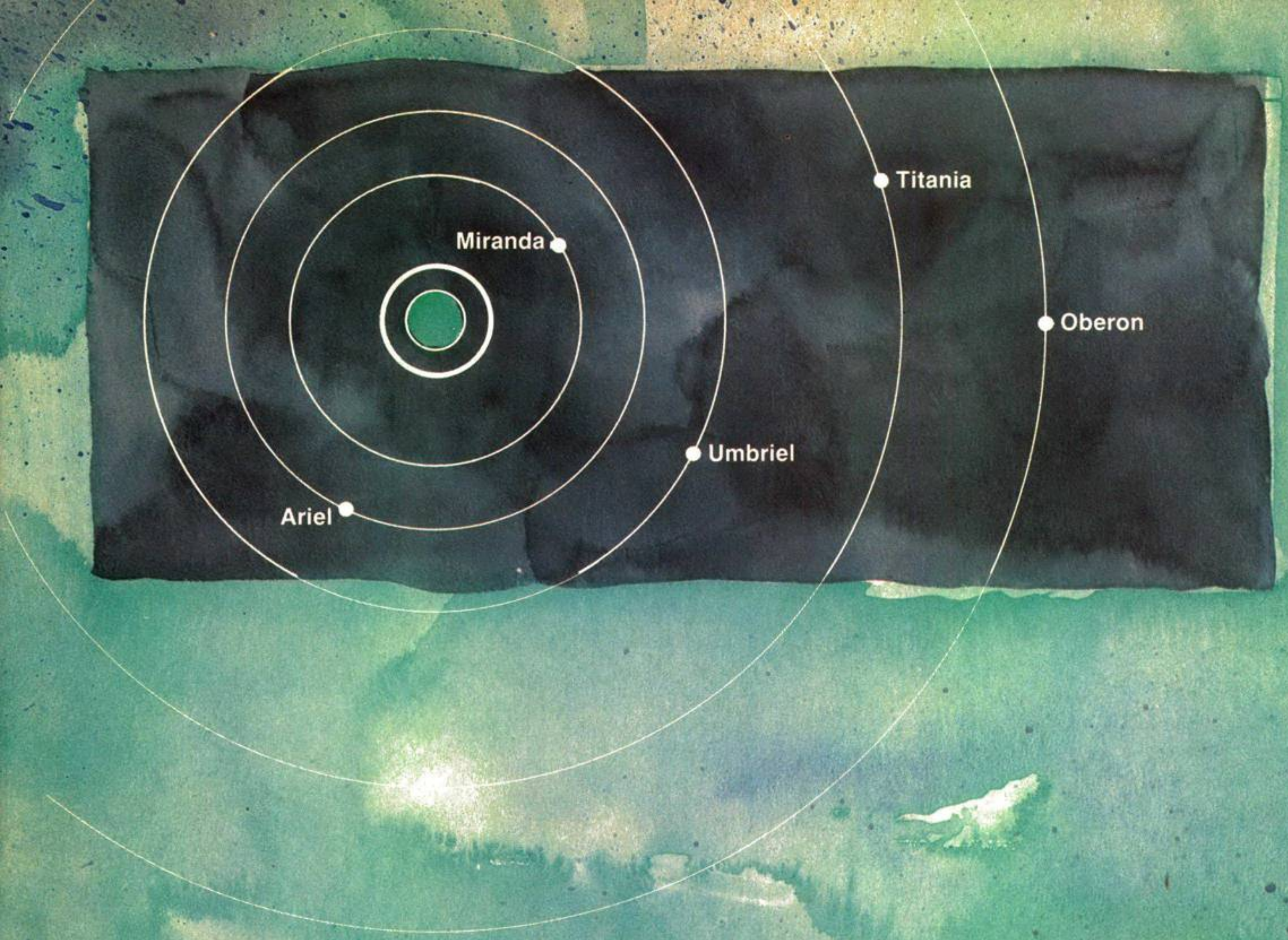
Although hydrogen and helium are the dominant components of Uranus' atmosphere, perhaps 3% of the upper atmosphere is methane. This figure is, however, very uncertain. Since methane contains carbon, this implies a carbon-to-hydrogen ratio which is dozens of times greater than that of the Sun. Jupiter and Saturn, in contrast, have carbon-to-hydrogen ratios similar to the Sun's.

This presents a problem: Because the gas-giant planets formed from a nebula with a composition similar to that of the Sun, astronomers expect such planets to have basically solar-like abundances. Therefore, light abundant elements such as hydrogen, helium, carbon, nitrogen, oxygen, and sulfur should be present in near-solar abundances in Uranus — but they aren't.

Although Uranus' atmosphere contains excess carbon, it suffers from a nitrogen deficiency and its atmosphere also has surprisingly little ammonia (NH_3). If ammonia is the principal nitrogen-bearing species, this implies a nitrogen-to-hydrogen ratio for the atmosphere which is 1% or less than that of the Sun. The atmospheres of Jupiter and Saturn, on the other hand, both have nearly solar nitrogen-to-hydrogen ratios. Why is there so little ammonia on Uranus? One possibility is that the ammonia reacts with hydrogen sulfide (H_2S) to form ammonium hydrosulfide (NH_4SH), which then precipitates out of the atmosphere as a solid. However, this reaction requires a lot of sulfur to work. Since we know nothing of Uranus' sulfur, astronomers admit they do not yet understand Uranus' lack of ammonia.

Uranus also presents a deuterium problem. Deuterium is an isotope of hydrogen. A normal hydrogen atom has only one proton, whereas a deuterium atom has both a proton and a neutron. Scientists have detected deuterium on Uranus in the form of the hydrogen deuteride molecule HD. HD is just like H_2 except that one of the two atoms in the molecule is deuterium.

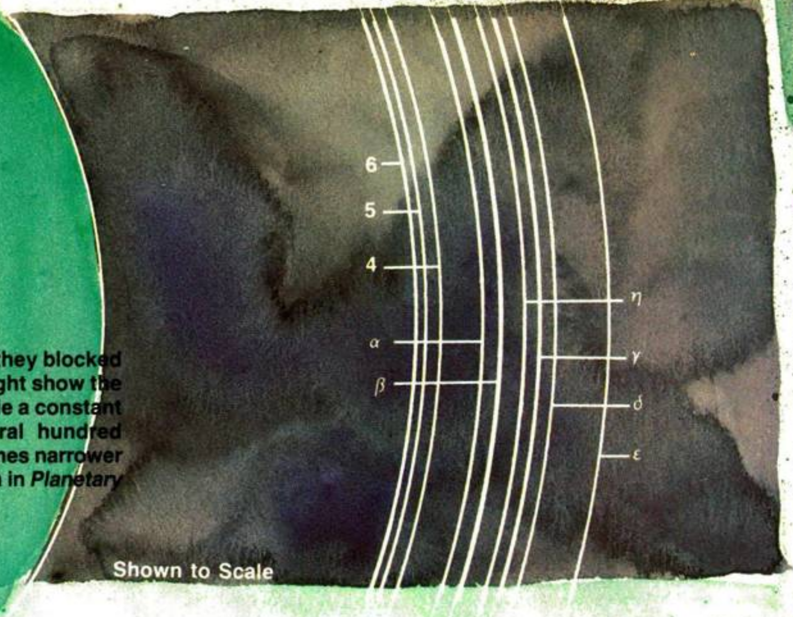
Deuterium may be present in any molecule in place of regular hydrogen. This means that molecules such as D_2O and HDO can exist, just as H_2O does. We can also



Satellite Data

Satellite	**Miranda**	**Ariel**	**Umbriel**	**Titania**	**Oberon**
Discoverer	Gerard Kuiper	William Lassell	William Lassell	William Herschel	William Herschel
Year of discovery	1948	1851	1851	1787	1787
Apparent visual magnitude	16.5	14.4	15.3	14.0	14.2
Distance from Uranus (km)	129,400	191,000	266,300	435,900	853,500
Revolution period (days)	1.414	2.520	4.144	8.706	13.463
Diameter (km)	500?	1330	1110	1600	1630
Orbital eccentricity	0.027	0.003	0.005	0.002	0.001
Orbital inclination (°)	4.22	0.31	0.36	0.14	0.10
Albedo	50%	30%	19%	23%	18%
Density	3?	1.3	1.4	2.7	2.6
Mass (Moon = 1)	0.002?	0.021	0.014	0.080	0.082

The Uranian Rings



Astronomers discovered the rings of Uranus when they blocked the light of a distant star. These recordings of starlight show the rings on both sides of the planet. Most of the rings lie a constant distance from Uranus, but the ε ring lies several hundred kilometers on opposite sides of the planet and becomes narrower when it's closer to Uranus. From Elliot and Nicholson in *Planetary Rings*.

Ring Data

Ring	Semi Major Axis (km)	Eccentricity	Inclination (°)	Width (km)	Comments
6	41880	0.00101	0.066	less than 2	Narrow; eccentric
5	42280	0.00185	0.050	less than 2	Narrow; eccentric
4	42610	0.00115	0.022	less than 2	Narrow; eccentric
α	44760	0.00078	0.017	varies from 5 at periapsis to 10 at apoapsis	At widest, this ring exhibits two components separated by ∼ 4 km.
β	45700	0.00043	0.006	varies from 5 at periapsis to 11 at apoapsis	Similar to α ring, but does not exhibit "double-dip" structure
η	47210	close to zero	close to zero	narrow: < 5 broad: 55	Has two components: a narrow one and a broad diffuse one
γ	47670	close to zero	0.006	3	Fairly opaque
δ	48340	0.00006	0.012	2 to 3	Fairly opaque; a diffuse component extends 12 km inside
ε	51190	0.00794	close to zero	varies from 20 at periapsis to 96 at apoapsis	Widest, most massive, and most eccentric ring

From Elliot and Nicholson in *Planetary Rings* (1984), page 25, and Elliot in *Uranus and Neptune* (1984), page 575.

have NH_2D and CH_3D, deuterated forms of NH_3 and CH_4. It turns out, in fact, that the deuterated molecules can form more easily than the "normal" molecules of water, ammonia, and methane. As a consequence, when Uranus formed, its water-ammonia-methane ice layer should have been enriched in deuterium-bearing molecules. In the 4.5 billion years since, some of this deuterium should have leaked into the atmosphere — if there is interaction between the ice layer and the atmosphere, as the abundance of methane in the atmosphere suggests. Therefore, astronomers would expect an enhanced deuterium abundance in the atmosphere. Yet spectroscopic observations show that the deuterium-to-hydrogen ratio is only slightly above the solar ratio, similar to those of Jupiter and Saturn.

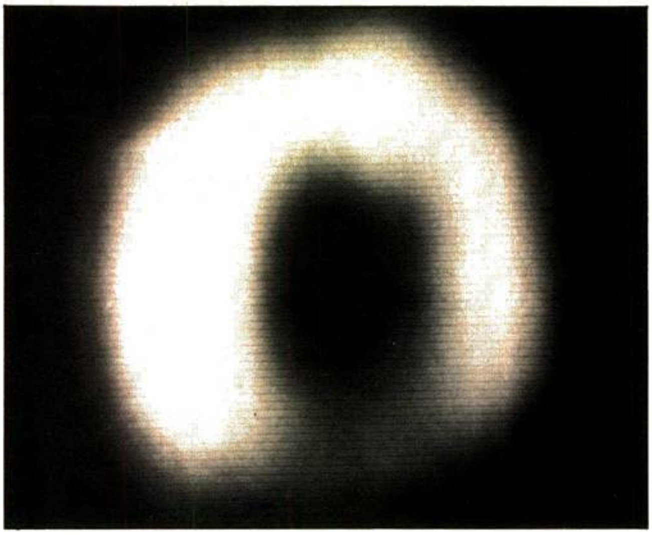
In addition to learning about the composition of Uranus' atmosphere, astronomers also want to learn about the atmosphere's structure. Its upper layers seem to be relatively clear so that sunlight penetrates to fairly great depths. However, the atmosphere might contain a haze composed of acetylene (C_2H_2) and/or ethane (C_2H_6). This haze may be more substantial at the equator, so the equatorial region of Uranus would appear somewhat darker than the pole. Below the haze could lie methane clouds and ammonia clouds — perhaps accounting for some of the observed depletion of ammonia in the atmosphere above them.

Aside from Uranus' overall green tinge, we really don't know what the planet looks like or what Voyager 2's cameras will see. Observers have occasionally reported dark bands on the planet, but many people don't believe these reports. Although Neptune exhibits weather features, Uranus, by comparison, seems relatively featureless. And that's all we know about Uranus' appearance — until Voyager 2 tells us more.

If Uranus proves rather featureless, it could be the result of a weak internal heat source. Jupiter's vigorous heat source is part of what keeps the jovian atmosphere so lively and colorful. Jupiter, Saturn, and Neptune all have strong internal heat sources: all three radiate more energy than they receive from the Sun. Neptune is actually the same temperature as Uranus, even though it lies a billion miles farther from the Sun. If Uranus lacks a strong internal heat source this may explain its quiescent atmosphere, but why the heat source should be weak would still remain a mystery. In any event, Voyager 2 should determine the strength of the planet's heat source accurately.

Another question Voyager 2 should answer is whether Uranus has a magnetic field. Jupiter, Saturn, and Earth all have strong magnetic fields which they generate from currents in their rotating cores. Since Uranus rotates at a rate similar to these planets, it may have a magnetic field as well. Some astronomers believe they have detected aurorae on Uranus, suggesting the planet does, indeed, have a magnetic field. Aurorae result when a planet's magnetic field directs charged particles from the Sun into its upper atmosphere. The glow resulting from the collision of these particles with the atmosphere is called an aurora. Voyager will determine the strength of any uranian magnetic field, which will, in turn, give scientists information on the planet's internal structure.

If Uranus does have a magnetic field, its interaction with the impinging solar wind should be quite interesting. The solar wind compresses the magnetic field on the side of the planet facing the Sun and draws it out into a long tail on the opposite side of the planet, forming a cocoon of charged particles called the magnetosphere.



Imaged in infrared light with the Hale 200-inch telescope, Uranus' rings show an uneven distribution of material. Caltech photograph.

One feature makes Uranus especially unique. While the other known planets of the solar system have rotational axes that are more or less perpendicular to the plane of the solar system, Uranus' rotational axis lies close to the plane of the solar system. The angle the Earth's rotation axis makes to the ecliptic is 23.5°; Uranus' axis, however, forms a 97.9° angle. The fact that this angle is greater than 90° means that Uranus, like Venus, rotates backward. In Venus' case, however, the rotational axis is still closely perpendicular to the plane of the solar system. At the present time, Uranus' axis points toward the Sun, so the solar wind impinges on Uranus' pole rather than its equator. (This should have very interesting effects on any uranian magnetosphere.)

Because Uranus lies on its side as it rotates, its poles receive more sunlight than does the equator. The poles will, on average, be somewhat warmer than the equator. Since a uranian year equals 84 Earth years, each season lasts about 21 years. Right now it's summer in Uranus' southern hemisphere, since the planet's south pole is pointing nearly straight toward the Sun and is bathed in constant sunlight. The northern hemisphere, on the other hand, is dark and the equator remains in perpetual twilight. Forty-two years from now, the opposite situation will hold: The north pole will face the Sun and the southern hemisphere will be in the grip of a very long winter. Between these two seasons, the entire planet is illuminated and the situation is similar to spring and fall here on Earth: the equator receives the most sunlight while the poles receive less.

Uranus' strange seasons must affect its weather patterns. When Voyager 2 visits Uranus, the planet's north pole will have been in darkness for many years, but scientists do not expect the southern hemisphere to be much warmer than the northern one. Uranus' massive atmosphere responds slowly to changes in sunlight. We all know from experience, of course, that Earth's thin atmosphere can heat dramatically in only a few hours, just as the temperature can plummet once the Sun goes down.

Although we expect Uranus' axial tilt to produce interesting effects with regard to the planet's magnetic field and seasons, no one knows how Uranus acquired this

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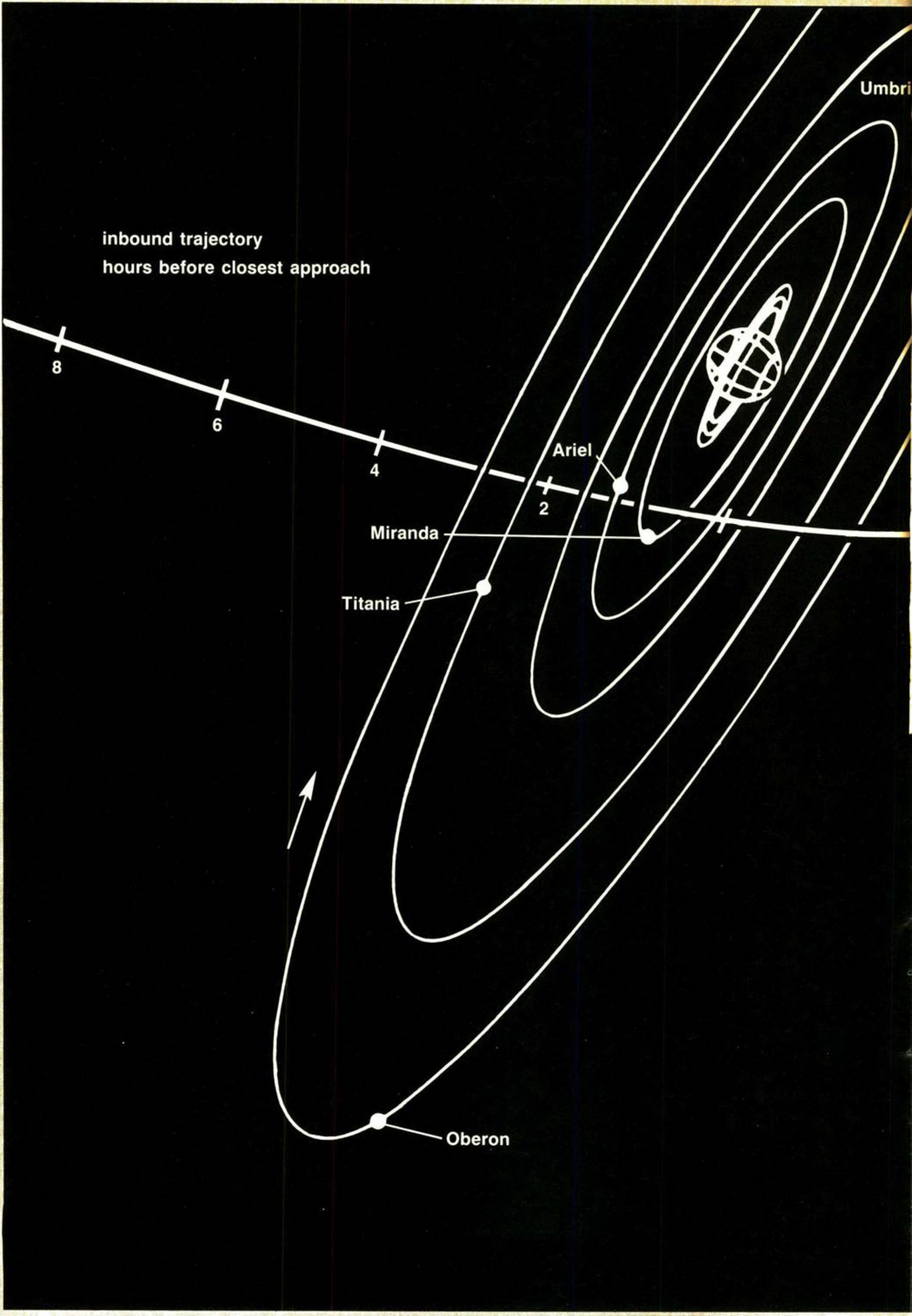
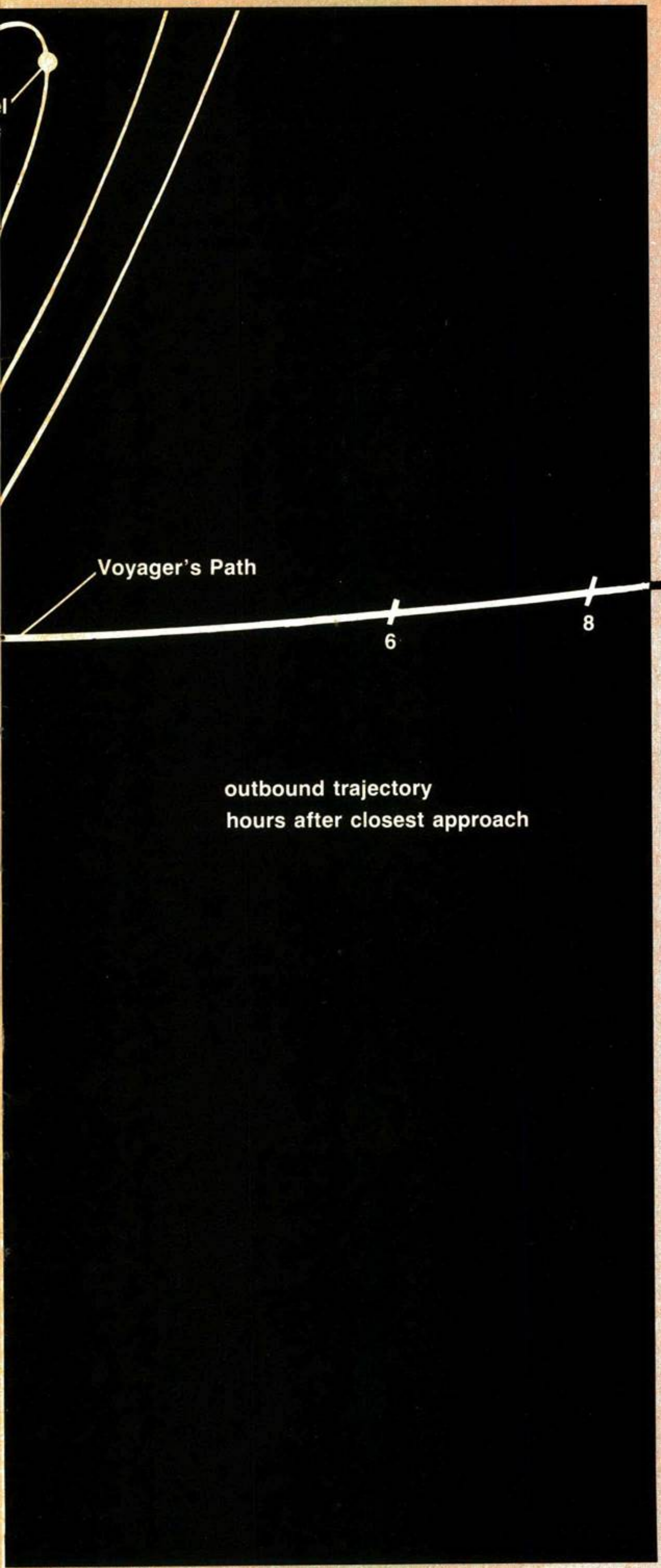

Umbri
inbound trajectory
hours before closest approach
8
6
4
2
Ariel
Miranda
Titania
Oberon



Voyager 2: Encounter with Uranus

by Gary L. Bennett

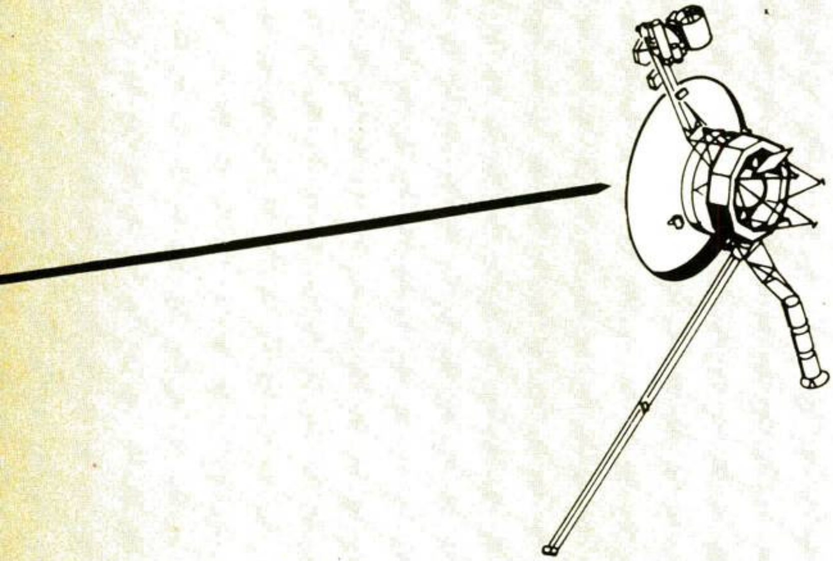
As these words appear, the 815-kilogram (1797-pound) Voyager 2 spacecraft is approaching the planet Uranus. It left Earth on August 20, 1977 at an initial speed of more than 10 kilometers per second. Using a rare alignment of the outer planets to hasten its journey, Voyager 2 has been flung by gravity from Jupiter to Saturn and from Saturn toward Uranus — the third largest planet in the solar system.

Voyager 2 and its twin, Voyager 1, have already provided the human race with more than 70,000 photographs of Jupiter and Saturn, their rings and satellites. However, Voyager 1 and 2 were not the first spacecraft to fly by these gas giants — Pioneer 10 and 11 led the way. Much was previously known about these two planets from Earth-based astronomy, but in a sense Uranus is still new territory despite almost 200 years of study. Even the best photographs taken from Earth show almost no detail and no spacecraft has visited this planet. This is not surprising when one realizes that Uranus is over 25 billion kilometers from Earth at its closest. Uranus is so far out that light and radio signals traveling at almost 300,000 kilometers per second take two hours and 45 minutes to reach Earth!

As Voyager 2 races along the final leg of its 4.8 billion-kilometer trip to Uranus, questions about this planet come naturally. What will Voyager 2 "see" as it flies past this mysterious giant? Why is Uranus tilted on its axis? What makes up the ring structure? What is the composition of Uranus? In short, what is Uranus like?

With 105 kilograms (232 pounds) of scientific instruments, Voyager 2 is well-equipped for our first reconnaissance of this unknown planet. Dr. David Morrison, a planetary astronomer and member of the Voyager Imaging Team, described the two Voyager spacecraft as "among the most autonomous, sophisticated robots ever sent to explore other worlds. Each is a self-contained system, carrying its own power, propulsion, communication systems, and science instruments." The Voyager 2 spacecraft carries wide and narrow-angle television cameras, a cosmic ray detector, infrared and ultraviolet spectrometers, magnetometers, a photopolarimeter, as well as instruments for measuring charged particles, plasmas, and radio emissions from or near Uranus.

To an observer traveling with Voyager 2, Uranus would



look like a bull's-eye centered inside its rings and satellites. The computer-controlled robot spacecraft will approach Uranus from the right, gaining speed as its gets closer, following a path that will enable the gravity of Uranus to deflect the spacecraft on toward Neptune. Months before encounter, telescope-equipped television cameras have been giving us better images of Uranus than we have seen with any telescope on Earth. Scientists are scanning these photographs, looking for structure in Uranus' atmosphere and for new satellites and rings.

A few Earth days before encounter — when Voyager 2 is less than 6 million kilometers from Uranus (still 15 times as far away as the Moon is from Earth) — Uranus will appear as large to Voyager's cameras as the Full Moon does from Earth. But Uranus will be only about two percent as bright because it receives much less sunlight than the Moon.

Scientists and engineers at the Jet Propulsion Laboratory will then selectively turn on the 10 scientific instruments and radio system to study the uranian system. Of particular interest is the uranian magnetic field, which will be monitored by the sensitive boom-mounted magnetometers carried by the spacecraft. The infrared interferometer spectrometer (IRIS) will be taking data on the composition, temperature, and structure of the atmosphere. The ultraviolet spectrometer (UVS) will also measure the structure and composition of the upper atmosphere, as well as auroral processes and the distribution of ions and neutral atoms. The JPL Planetary Radio Astronomy Team will search for radio bursts which could indicate lightning in the atmosphere of Uranus or electrical discharges within the ring system.

On January 24, 1986, Voyager 2 will pass 107,080 kilometers from Uranus. On this path, cameras will catch Miranda and Ariel — Uranus' innermost two satellites — from distances of 29,000 kilometers and 127,000 kilometers, respectively.

At closest approach, Uranus will loom like a giant, half-shadowed greenish sphere about 55 times the diameter of the Moon as seen from Earth, with a total brightness almost equal to our Moon seen from Earth. An observer on board Voyager 2 would see Uranus pass through phases similar to those of the Moon as Voyager flies by the planet. At the time of closest approach, over half of Uranus' surface will be dark.

Uranian gravity will bend Voyager's trajectory 23° and increase its speed almost 2 kilometers per second (1.2 miles per second); an observer would see a complete night over the northern pole of Uranus. Then as Voyager 2 whips past the planet, it will radio pictures back to Earth showing the human race its first "sunrise" over Uranus.

Because Voyager 2 is twice as far from Earth as it was at Saturn, the spacecraft can only return data at one-fourth the rate as at Saturn. The pole-sunward orientation of Uranus will reduce the time available for close observations. Furthermore, since the flyby of Uranus and its five known satellites will last a mere five and a half hours, compared to the 13 days of close approaches to Saturn and its satellites, time will be limited. This requires careful operation of the scientific instruments and "digital data compression" of the photographs. Because of this, the mission planners expect to take only 250 to 300 pictures during the 24 hours surrounding closest approach.

Despite these limitations, the photographs will show features 20 kilometers across — 300 times better than what has been seen from Earth. Some blurring may occur because of spacecraft motion while the camera makes time exposures — necessary because of the weak sunlight at Uranus. In case Voyager 2 suffers a recurrence of the scan platform seizure, the JPL Flight Engineering Office has developed an alternative method of pointing — they will rotate the entire spacecraft to obtain pictures. In fact, to reduce wear and tear on the platform drive gears, they will roll the spacecraft whenever possible rather than moving the scan platform.

To carry out its mission so far from Earth, Voyager 2 relies on computer controls and nuclear power. Three nuclear power sources called radioisotope thermoelectric generators (RTGs) provide all the electrical power needed to keep the spacecraft and its computer systems operating. These RTGs have produced more than 30,000 kilowatt-hours of energy for Voyager 2 — enough to power the water systems and appliances of over 50 houses for a month!

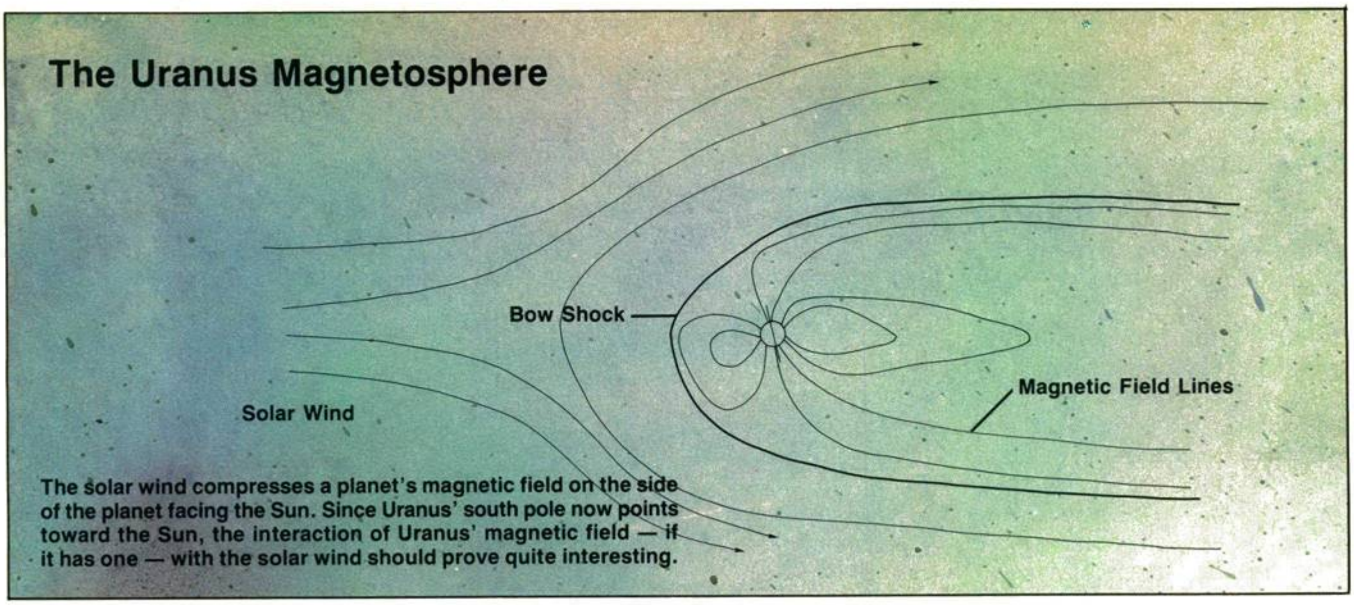
After visiting Uranus, Voyager 2 will speed on toward an encounter with Neptune planned for August 14, 1989. If the spacecraft continues to function satisfactorily, we will then see this last giant planet — and perhaps learn why Neptune is both so similar and dissimilar to Uranus. Voyager 1 and 2 surprised us at Jupiter and Saturn — planets we knew more about. We can expect many surprises at Uranus and Neptune — planets of which we know very little.

What will happen to Voyager 2? JPL analysts have estimated that there will be sufficient electrical power from the RTGs to maintain communications until early into the 21st century. Voyager 2 and its interstellar companions — Voyager 1, Pioneer 10, and Pioneer 11 — may provide us with our first information on interstellar space and the cometary debris that has been postulated to affect Earth's climate. Some 357,900 years from now, Voyager 2 will pass about 0.8 light-year (almost 5 trillion miles) from Sirius, now the brightest star in the heavens.

It is intriguing to imagine what would happen if some extraterrestrial life form chanced upon Voyager 2. Perhaps such a life form might find and decipher the special sound-and-light show placed on board Voyager 2 to describe Earth. Included is this greeting from President Jimmy Carter:

"This is a present from a small, distant world. A token of our sounds, our science, our images, our music, our thoughts and our feelings. We are attempting to survive our time so we may live into yours. We hope some day, having solved the problems we face, to join a community of galactic civilizations. This record represents our hope and our determination."

Voyager 2 also represents our hope and our determination.



The Uranus Magnetosphere

The solar wind compresses a planet's magnetic field on the side of the planet facing the Sun. Since Uranus' south pole now points toward the Sun, the interaction of Uranus' magnetic field — if it has one — with the solar wind should prove quite interesting.

strange tilt in the first place. Perhaps a large asteroid or planetesimal smashed into Uranus as it was forming, altering a near-normal spin. Voyager 2 will probably not be able to answer this question though it could provide important clues.

The Satellites of Uranus

In its encounters with Jupiter and Saturn, Voyager showed us that satellites are just as interesting as the planets they orbit. Uranus' five known moons are not only smaller, but also more distant than the major moons of Jupiter and Saturn, so planetary scientists know even less about them.

There are seven large moons in the solar system; Uranus is the only giant planet without any. Earth has the Moon; Jupiter has Io, Europa, Ganymede, and Callisto; Saturn has Titan; and Neptune has Triton. But Uranus has only a retinue of tiny worlds. The diameters of Uranus' largest moons, in fact, are less than half those of the "big four" Galilean satellites of Jupiter.

In order of their distance from Uranus, the five known satellites are Miranda, Ariel, Umbriel, Titania, and Oberon. The two outermost moons — Titania and Oberon — are also the largest. William Herschel discovered them in 1787 only six years after he found Uranus. William Lassell sighted Ariel and Umbriel in 1851; it was he who discovered Neptune's large moon Triton shortly after that planet's discovery. Tiny Miranda always huddles close to Uranus and so eluded astronomers until 1948, when Gerard Kuiper detected it with the 82-inch telescope at McDonald Observatory. The next year, Kuiper discovered Neptune's other known satellite, Nereid.

In the last few years, astronomers have discovered that Uranus' moons are darker than previously thought. Because our estimates of their diameters are based on their brightnesses, this increases the diameters we assign them since a dark body must be larger in order to reflect the same amount of light to us. Infrared spectra indicate that all five of Uranus' satellites have surfaces of dirty water ice.

Miranda, the innermost satellite, is also the smallest; with a diameter of about 500 kilometers, it is smaller than the asteroid Ceres. Miranda seems to have the highest reflectivity (i.e., the whitest surface) of the five satellites. The next two satellites, Ariel and Umbriel, have diameters between 1000 and 1400 kilometers. Both seem to have low densities, roughly 1.4 times that of water, suggesting they contain a lot of water ice. In contrast, the two outermost moons — Titania and Oberon — have densities twice as great as Ariel and Umbriel, suggesting a greater abundance of silicate rock. Titania and Oberon are the largest of Uranus' moons, with diameters of nearly 1600 kilometers.

The four outer moons exhibit increased density in relation to distance from the planet: Ariel and Umbriel are half as dense as Titania and Oberon. Jupiter's satellite system shows the opposite behavior: the inner Galilean satellites — Io and Europa — are much denser than the outer two — Ganymede and Callisto. Of course, the densities and diameters of Uranus' moons are still poorly known, whereas we have precise quantities for Jupiter's four large moons.

Uranus' strange axial tilt strongly suggests some catastrophe occurred — perhaps an asteroid hit the planet in the past. However, another consequence of such an event would be a very disordered satellite system — yet Uranus possesses the most orderly satellite system in the solar system. The outermost four moons have nearly circular orbits with little inclination to Uranus' equator; only Miranda shows a slightly eccentric and inclined orbit similar to but much less extreme than that of the innermost planet of the solar system, Mercury. Ironically, Uranus' twin planet Neptune, with its rather ordinary axial tilt of 29°, has the most chaotic satellite system we know: Triton orbits Neptune backward in an orbit inclined 21° to the planet's equator, and Nereid's orbit is the most eccentric of any satellite's in the solar system.

Voyager 2 will investigate Uranus' satellites and in doing so may make the most exciting discoveries of the Uranus mission. However, since Uranus' south pole now points almost directly toward the Sun (and Voyager 2's inbound trajectory), the logistics are difficult. All Uranus' satellites orbit in a plane which the incoming spacecraft will view pretty much face on. At Jupiter and Saturn, Voyager traveled near the plane of the satellites. Its cameras could study one moon, then move on to the next. At Uranus, unfortunately, Voyager 2 will plunge through the satellite plane rather than travel within it and will essentially encounter all Uranus' satellites at once rather than individually. This means Voyager 2 will view some satellites from a greater distance than we would like. (See "Voyager To Uranus and Neptune," ASTRONOMY, April 1983.) Not entirely by chance, Voyager 2 will pass closest to the moon we know least about: tiny Miranda.

Despite the drawbacks, Voyager 2 should provide good views of each satellite and give personality to those five points of light about which we now know so little. Accurate determinations of their diameters, densities, and albedos are almost assured, so clues about their compositions are also possible. Scientists will also be interested in studying their past evolution. In addition, Uranus could have more than five moons. The fact that only five are known may be as much a result of Uranus' distance from our telescopes as it is of the planet's small mass. Some scientists, in fact, believe Uranus *must* have many more moons — in order to maintain the observed structure of the planet's rings.

The Rings of Uranus

Uranus is such a remote world that astronomers have had to resort to desperate means to learn more about it. As Uranus slowly orbits the Sun, it occasionally passes in front of a star as viewed from Earth. The exact way in which the star fades as its light passes through Uranus' atmosphere allows astronomers to probe the atmosphere's structure. Furthermore, the duration of these eclipses has given us the best estimates we have of the planet's imprecisely-known diameter.

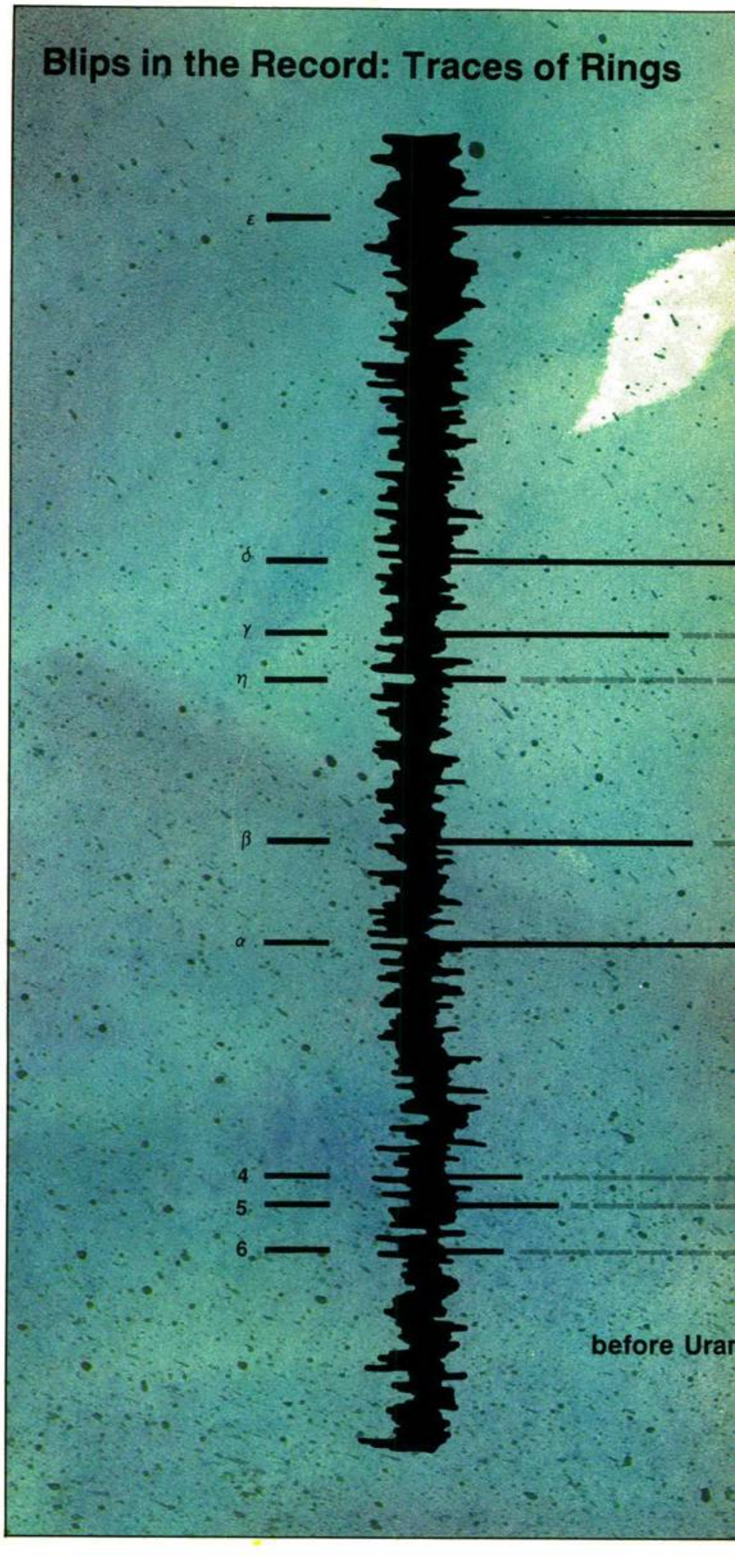
On March 10, 1977, Uranus eclipsed the ninth-magnitude star SAO 158687 in the constellation Libra. In order to view the event, astronomer James Elliot and his colleagues flew the NASA Kuiper Airborne Observatory over the Indian Ocean.

Forty minutes before Uranus occulted the star, the outermost of Uranus' rings — the ε ring — eclipsed the star. At first, the scientists assumed the event was caused by a problem with their equipment or cloud interference, but the meteorologist aboard reported the sky was perfectly clear.

Four minutes later, the next ring — the δ ring — eclipsed the star. The scientists' suspicions again turned to clouds, but once again, the meteorologist reported there were none. At this point, Elliot joked that these events could be the rings of Uranus, which produced general laughter aboard the plane.

The astronomers detected several other such events before and after the Uranus occultation. In discussing what caused them, they decided to report the discovery of a "swarm of satellites" around Uranus. They also considered rings, but these seemed unlikely because most of the events lasted only a second or two, suggesting very narrow rings — quite improbable considering Saturn's broad rings.

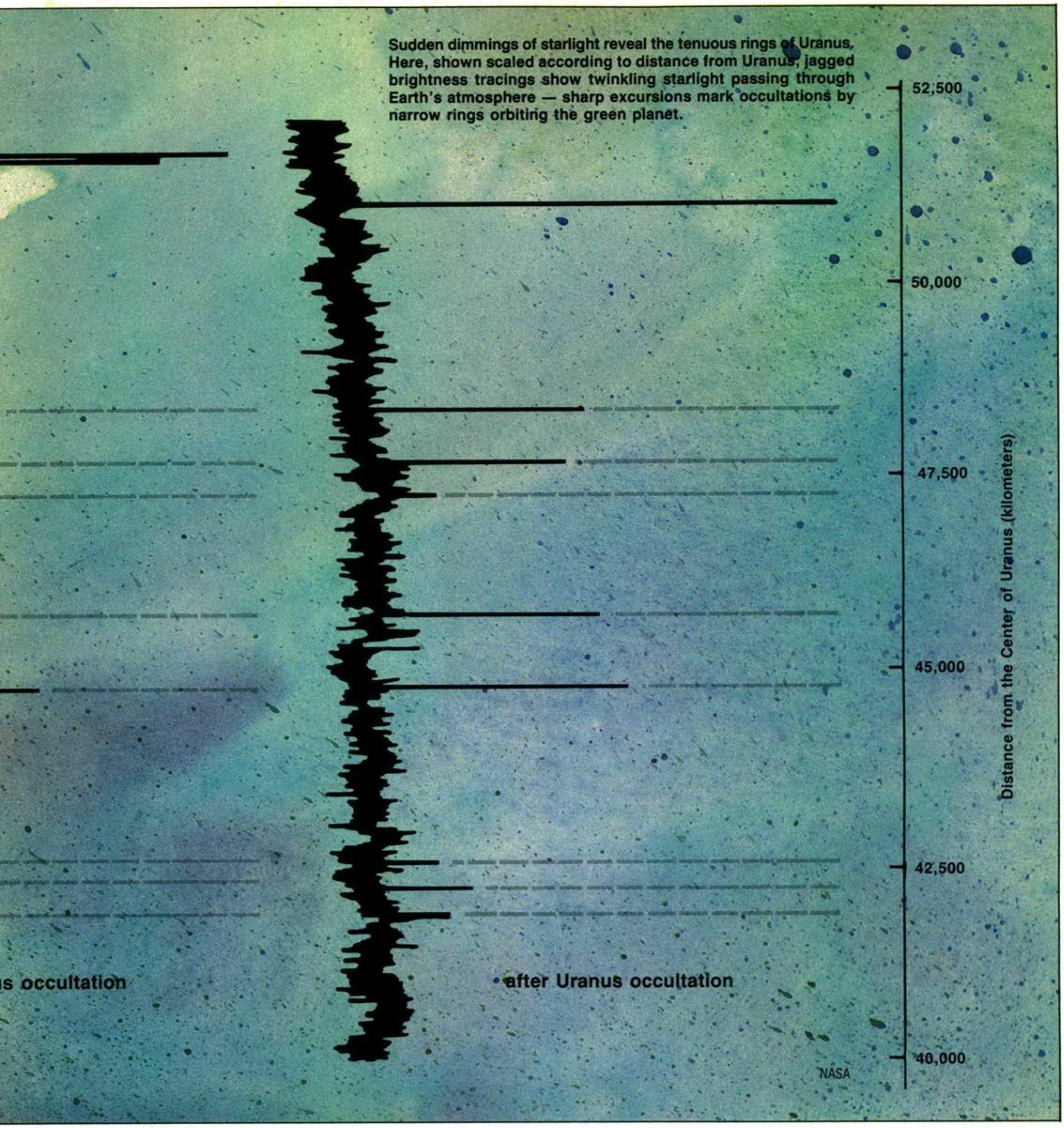
But Uranus' rings are actually very different from Saturn's. The next day, Elliot discovered the objects were indeed rings when he compared the pre-eclipse and post-eclipse events. He found that each eclipse prior to occultation had a counterpart after occultation, ruling out the "swarm of satellites" hypothesis. At first the scientists reported five rings, but we now know Uranus has at least nine. In order of their distance from the planet, the rings are named 6, 5, 4, α, β, η, γ, δ, and ε.



Blips in the Record: Traces of Rings

While Saturn's beautiful rings are bright and broad, Uranus' are dark and narrow. The albedo of Uranus' rings is only 2% to 3% — as dark as the darkest asteroids. The low albedo along with recent spectroscopic measurements suggests the rings are not icy — an unexpected result since ice is very common in the outer solar system. (It occurs on all five of Uranus' moons, for example.)

The inner three rings of Uranus — the 6, 5, and 4 rings — are very narrow and eccentric, each less than two kilometers wide. The next ring, the α ring, varies in width from five kilometers at periapsis (closest point to Uranus) to 10 kilometers at apoapsis (farthest point from Uranus). The α ring also exhibits a "double-dip" structure at its widest point, where it breaks into two components with a thin spot in the center. The β ring is similar to the α ring, varying in width from five kilometers at periapsis to 11 kilometers at apoapsis, but it does not show the "double-



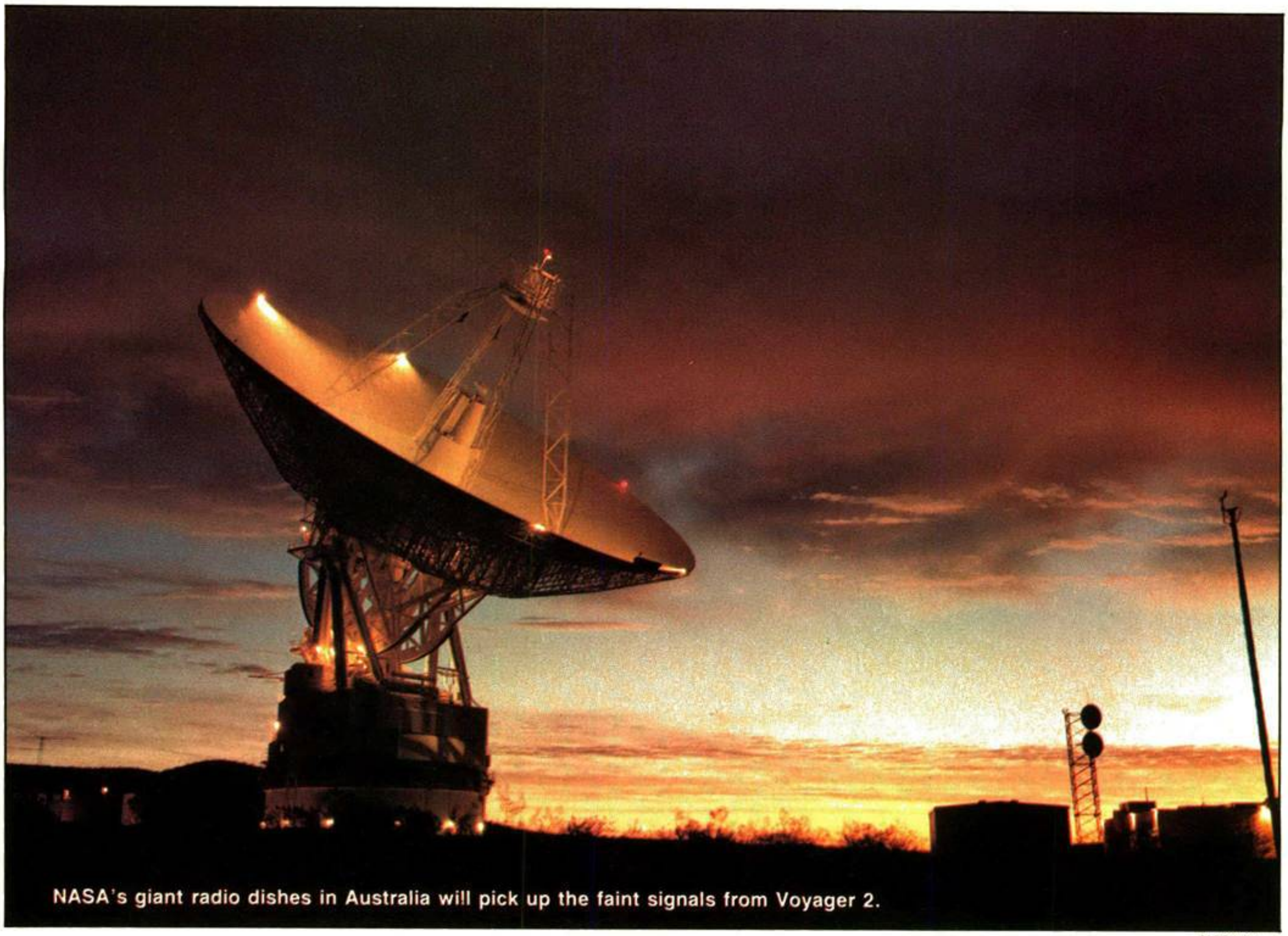
Sudden dimmings of starlight reveal the tenuous rings of Uranus. Here, shown scaled according to distance from Uranus, jagged brightness tracings show twinkling starlight passing through Earth's atmosphere — sharp excursions mark occultations by narrow rings orbiting the green planet.

dip" structure of the α ring.

The η ring consists of two components: one is narrow and less than two kilometers wide; the other is broad and diffuse, extending some 55 kilometers outward from the narrow component. The γ and δ rings seem similar to one another: each is about three kilometers wide and fairly opaque. The δ ring has a diffuse component extending 12 kilometers inside the narrow component.

The outermost of Uranus' rings is the ε ring, which contains more mass than all the others put together. The ε ring varies in width from 20 kilometers at periapsis to 96 kilometers at apoapsis and is by far the most eccentric ring, having an orbital eccentricity of nearly 0.008.

The uranian rings have puzzled astronomers since their discovery. What holds them together? What keeps them so narrow? According to one theory, a small satellite orbits inside each ring and holds it together. A more likely theory, however, was proposed by Peter Goldreich and Scott Tremaine in 1979: they suggest small satellites orbit Uranus between the rings, confining the particles of the rings and maintaining the structure. In 1980, Voyager 1 discovered two such satellites tending the narrow F ring of Saturn; will Voyager 2 discover "shepherd" satellites herding the uranian rings as well?



NASA's giant radio dishes in Australia will pick up the faint signals from Voyager 2.

NASA Photo

Because the rings are so small and dark, photographs of them may not be very spectacular. Voyager 2's cameras will be programmed to search for inter-ring material and rings too delicate to detect by stellar occultation. The spacecraft will also beam radio signals through the rings, observe stellar occultations produced by the rings, and view the rings from behind. These observations should tell astronomers more about the structure of the rings and the sizes of the particles composing them.

All This, and Voyager Two

Uranus is a fascinating and mysterious world. Never before have we sent a spacecraft to a place about which we knew so little. Astronomers had lots of unanswered questions about Mars prior to Mariner 4's visit in 1965, but we knew far more about Mars then than we do about Uranus today.

What can we expect from Voyager 2? If all goes well, we will, for the first time, see what Uranus looks like. Does it have dark bands, as some observers have reported, or is it bland? Does it show belts and zones as Jupiter does, and do great storms rage in its atmosphere, akin to the Great Red Spot?

Voyager will investigate the structure, dynamics, and composition of Uranus' atmosphere. Scientists hope to determine the planet's atmospheric temperature and pressure profiles, and they expect to determine the atmosphere's helium-to-hydrogen ratio — all data to let them model a planet never seen before in sufficient detail.

Voyager 2 will measure Uranus' diameter to unprecedented accuracy, and from that and the planet's mass we will learn its density. The spacecraft will also determine the planet's oblateness. If Uranus has a strong magnetic field, Voyager 2 will find it. The spacecraft should also determine the length of the uranian day. These data will constrain models for the planet, giving us clues about the planet's interior.

In what may turn out to be one of the major highlights of the Voyager 2 mission, the spacecraft will send back the first good photographs of Uranus' five known satellites. And it could well discover more. Voyager 2 will determine the diameters, densities, and albedos of the moons, giving us clues to their composition.

In its investigation of Uranus' rings, Voyager 2 may well find that the ring system is far more complex than we think. We know they are eccentric, but Voyager may reveal that Uranus has braided and kinky rings, as does Saturn. It may solve the mystery of what holds the rings together — or deepen the mystery with perplexing new detail.

It is often the unexpected that makes a voyage to a new place memorable. Who could have foreseen the discovery of Mars's great canyon, Io's relentless volcanoes, or Titan's abundance of nitrogen gas? What totally unexpected things will Voyager 2 discover at Uranus?

Now, just months before the encounter, we can only wait with anticipation.

A graduate student at Harvard University, science writer Ken Croswell frequently appears in ASTRONOMY. His most recent contribution, "When Stars Coalesce," was published in the May 1985 issue.

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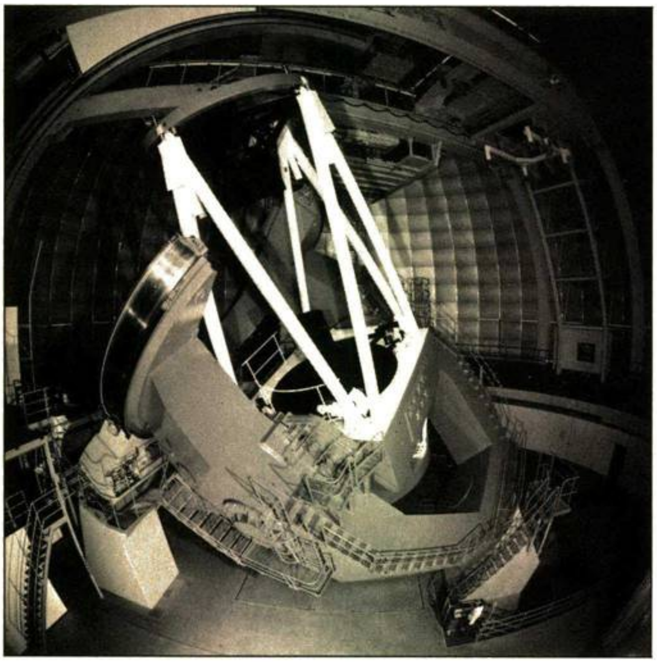

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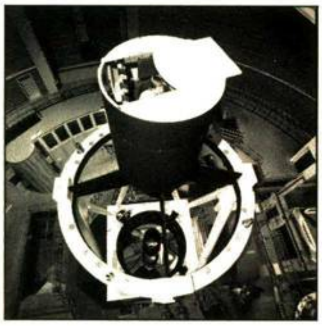

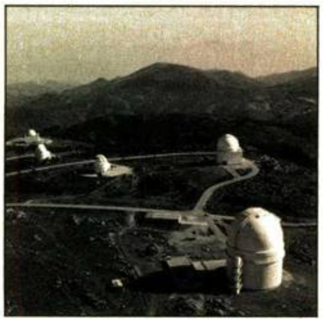

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ASTRONOMY
Forum

Texas Star Party, 1985

" — has turned off the seat belt sign. We remind you there is no smoking in the lavatory . . . if we catch you smoking in there, not only will you lose your lavatory privileges, we'll ask you to leave the aircraft immediately."

Eight a.m. and ten minutes out of Milwaukee, our 727 was passing south of Madison en route to El Paso by way of Denver. A little farther west, dense morning fog filled the Wisconsin River valley. Onward and westward. Over the plains, haze began to collect and thicken below as we penetrated a warm front. Landing at Denver meant bouncing in dirty-lint clouds for half an hour and then a low fast swoop onto the runway. In the distance, cold wet rock poked through fresh snow on the Front Range of the Rockies.

Southbound after changing planes, we exited the clouds near Albuquerque. The next landmark lay west of Socorro, where the National Radio Astronomy Observatory's Very Large Array radio telescope formed a tiny Y-pattern of white dots set in a dry and wrinkled landscape. Five miles below and about 10 miles to starboard, it didn't look like much.

El Paso was crystal clear: sunny, 90°, and dry. After picking up my rental car (thinking thermally, I'd asked for a white one) and looking in vain for a sunhat, I headed east on I-10. Three hours later I reached Kent, where Texas 118 snakes south from the interstate into the Davis Mountains. Cautioned by signs to "Drive Friendly," I kept a sharp eye out for livestock on the road which in places runs through range land. An hour later and nearing the site, I had climbed slowly out of the desert into elevations where the land was just lush enough to call chaparral. I saw many vultures, black silhouettes cruising the thermals — road kills get recycled quickly here.

The Texas Star Party is held each year at the Prude Ranch, named for the family that has run it since the late 1890s. It lies on bottom land about five miles up Limpia Creek Canyon from Ft. Davis. The ranch is at an elevation of 4,400 feet; from a ridge on the west that overlooks the main buildings, you can see the white domes of McDonald Observatory on Mt. Locke about six miles away (12 miles by road). As an observing site, you could hardly ask for better: clear weather, generally dry climate, moderate altitude, and very few neighbors. (The population of Ft. Davis in the last census was 850.)

It was late afternoon when I parked the car in the dusty shade of a large cottonwood and went into the ranch office to register. Assigned to Walnut Cabin, I headed off to find it, selected a room (all were still empty), and unpacked.

This first afternoon (Monday, May 13th) was two days before the official opening of the Star Party, but a number of people had already arrived — some even on the weekend. After dinner, I loaded the cameras and went for a walk around.

Three areas had been set aside for observers. As you come in the main gate, there is a broad expanse for people who are camping. Then just behind the horse corral and dining hall is another campers' field, but with electric outlets. Most of the cabins, including Walnut, fronted this field. Behind the cabins was a large football field, fringed on the west by more cabins, that was also provided with outlets on extension cords. Most people set up their scopes on either the football or corral field.

Before it got dark, I talked to one fellow whose 10-inch Cave Dall-Kirkham Cassegrain was mounted on a pier stabilized with chains. He said that before installing the chains, the pier would whipsaw in the slightest breeze. He ran chains (with turnbuckles for adjustment) from the top of the pier down to the ends of each of the three legs. A fourth chain held the three leg ends in place. We both wondered why more telescope owners don't brace their piers.

As dusk came on, many of the telescopes were still unattended. It seemed like the sole time you could get people together with their scopes was after dark — useless for taking pictures, given the dusk-to-dawn ban on lighting. (Only red-lensed flashlights are permitted, though I saw a few whose "kilowatt" output partially defeated the intent of the rule.)

After sunset, the clear sky quickly darkened and the air temperature dropped sharply. I went back to exchange shorts, shirt, and sandals for long pants, shoes, turtleneck, sweater, parka shell, and gloves. By the time it darkened enough to see the zodiacal light — which was so bright as to make you think it was lingering twilight — a cold wedge of wind was drifting down from the ridge and across the telescopes. I set up one camera with a 28mm lens on a tripod looking south over the assembled scopes, opened the shutter, and walked away.

The zodiacal light was a soft triangular glow whose edge was more distinct in averted vision. It climbed over the western ridge and followed the ecliptic from Gemini through Cancer (nearly obliterating the Beehive to the naked eye) and ran on well into Leo. Bright? Well, put it this way: If you'd wanted to look for faint objects in this area, you'd have found the zodiacal light a nuisance. Depending on your eyesight, you could trace it (or the zodiacal band) an amazing distance. I lost sight of it in western Virgo, but overheard one fellow —

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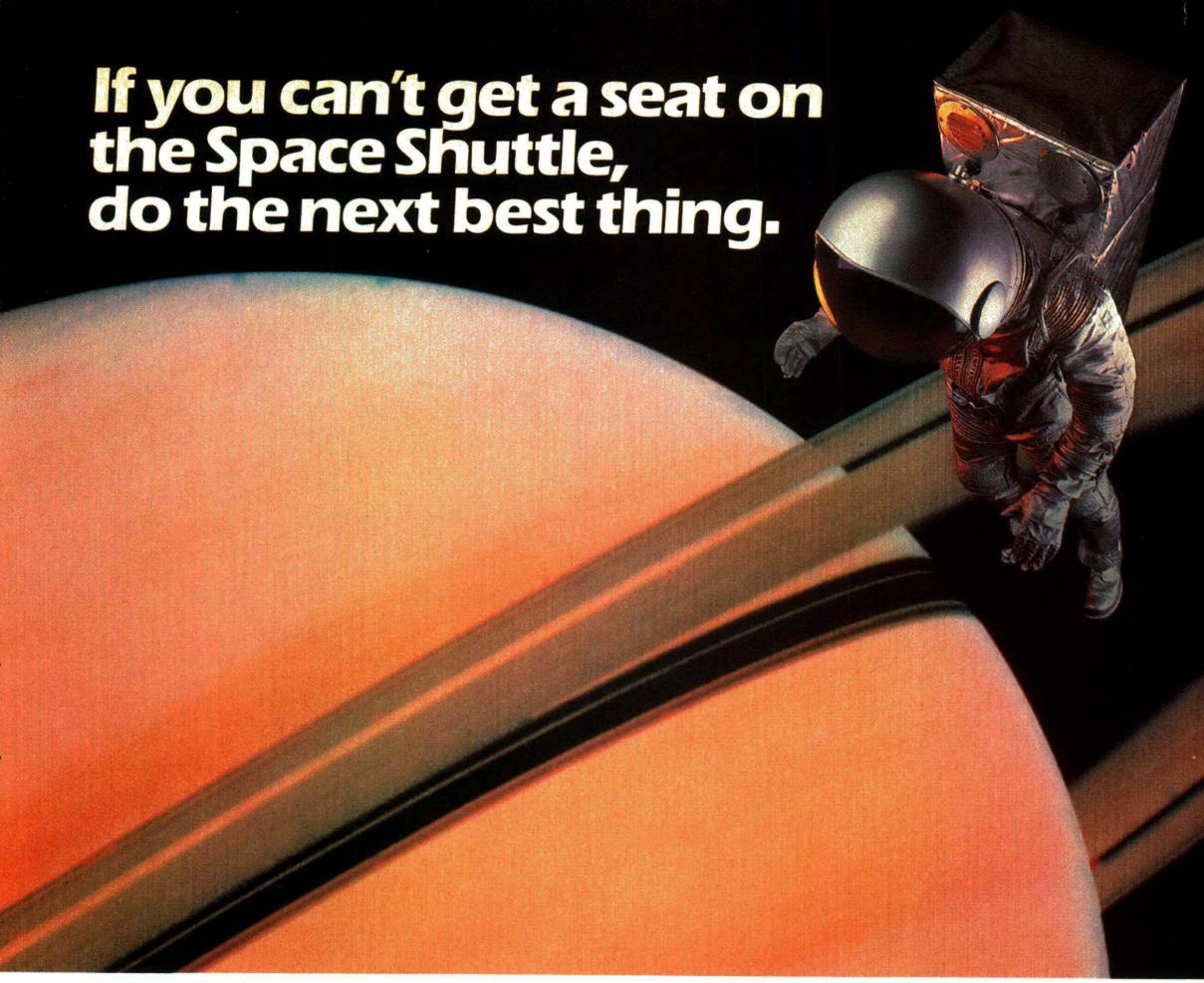

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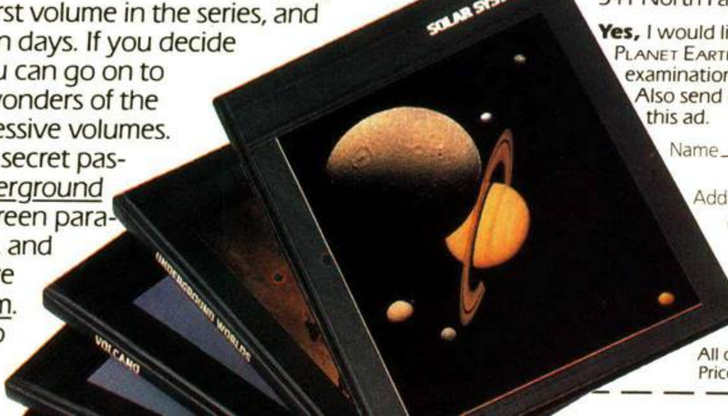

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perhaps better dark-adapted — claim to follow it down into Libra.

Aside from dark skies, the Texas Star Party — held at a latitude of 30.6° north — gives us northerners a chance to see things lost below our southern horizons. (Milwaukee is at 43° north.) In particular, I was keen on seeing two Centaurus items: NGC-5128, the galaxy also known as radio source Centaurus A, and Omega Centauri, the biggest and brightest globular cluster in the sky. I expected to see them in a telescope; what took me by surprise was seeing Omega easily with the naked eye and spotting 5128 clearly in my 7x50s.

John Wagoner had his 16-inch Dobsonian ready and we compared M-13 in Hercules with Omega, both at 60x. Though still low at that point, M-13 was very impressive, perhaps the best I've seen it in recent years. "Star chains" seemed to radiate outward, and the ball was resolved right across its face. Yet when we turned the scope to Omega, I understood the immense appeal this southern object has — even for those to whom a globular is just a fuzzy celestial tennis ball.

Whereas M-13 had occupied the center of the field of view, it was encircled by lots of dark sky. Omega was profoundly different: It filled only the central one-third to one-half of the field, but gave the impression of occupying far more — I felt as if a long-exposure photo would show Omega's stars bursting out of the entire field of view. Omega seemed slightly elongated in the east-west direction and was resolved all the way across, though the generally poor seeing kept the resolution "shimmery." Overall, I've never seen as impressive a deep-sky object.

Centaurus A was equally exciting, though less spectacular. In the 16-inch at 60x, the dark lane appeared as a faint extension of sky bisecting two dim glows — with the dark lane as wide as each of the two outer parts, the whole thing reminded me of a hamburger!

Around midnight, the cold downslope draft from the west ceased and was replaced by a warm and fitful wind from the northeast. The seeing degraded further. By now I was fully dark-adapted. I can always tell: the sky stops looking black and becomes dark grey. The faint glow comes from several sources, principally starlight, residual zodiacal light, and airglow — this last being the weak luminance of the atmosphere itself.

Although the sky was extremely transparent, the seeing was terrible: stars were 1 arc-second moving blobs. It was ideal for galaxy hunters, but miserable for anyone seeking double stars or trying to observe Saturn. I suddenly remembered the star trail photo I was taking, found the camera, and started another shot looking north from the south end of the field.

I then wandered over to join the group looking through Pierre Schwaar's 20-inch, whose main mirror had been ground by Pierre himself. It was aimed at Hercules, so I guessed M-13 was the target — a guess confirmed when I reached the eyepiece and looked in. The image was very fine, but seeing was too poor for satisfactory views even at low power.

Around 2:30 a.m., the Scorpius-Sagittarius section of the Milky Way was nearing the meridian. Earlier, I'd cast an appreciative eye to the east as the Milky Way was rising. Warned in advance how dramatic it was, I didn't make a fool of myself by cursing the oncoming "moonlight" or "clouds" — but I understood how this might happen. Seen out of the corner of your eye, the rising Milky Way looked exactly like a cloud bank moving in. It was eerie — I'd never before seen the dark rift in Sagitta and Vulpecula when it was so low to the horizon. You could actually see the rift as soon as it cleared the hilltops to the east!

I went off to a quiet spot, sat down, and started scanning idly with my 7x50s. (Tirion's star atlas was back in the cabin and I was too lazy to go get it.) Picking up M-objects was a joke. Even at 7x hand-held, I found 10 or 12 in the lower Milky Way without really trying, and knew I could have seen many more with higher magnification and a brace to hold the binocs. It was wonderful just to sit and look up at such a beautiful sky. All around were murmured conversations (a lot fewer now than earlier) and the intermittent red "fireflies" of flashlights.

Abruptly, I realized I'd been staring at the same piece of sky for five minutes with nothing registering, and got creakily to my feet. The long day had finally taken its due and the bunkhouse was calling silently but insistently.

I got up Tuesday at 8:30, did some shopping in Ft. Davis, and looked over the scopes until noon. After lunch, I ran into Ed Boutwell, a tall, lanky Alabaman who has a small observatory — "Boutwell's Folly" he nicknames it — with an equatorially-mounted 16-inch on the western ridge overlooking the TSP grounds. The Prudes donated the land for it and Ed lent the scope and built the observatory, officially named for Edmond Halley. I made a mental promise (unfortunately not kept) to visit it after dark, since it is nearly as high as the surrounding hills. The daytime view was spectacular.

Later in the afternoon, I spent an hour talking to Mace Hooley, an Arkansas astrophotographer who showed me a fantastic Milky Way shot he'd taken at 3 a.m. the night before. We talked a bit about some articles he's working on for ASTRONOMY.

After dinner, I got to see in action the technological *tour de force* of this year's TSP, a computer-controlled 24-inch. Mounted on metal alt-azimuth bearings, it could take the name of a star and find the object (if the star was in the database) or it would go to whatever coordinates you chose. You erect the mounting, level it with adjustable feet, and then point it at an object whose coordinates you know. With the object centered, you tell the computer what it's looking at and that's all there is to aligning the mounting. It's not an equatorial, so the field slowly rotates as the scope tracks. As it slewed swiftly from one part of the sky to another, you hear a high-pitched whirr.

When it got dark, I gathered my night gear and headed for Mike Planchon's homemade binocular holder. This is a simple frame of 2x4's that fitted over a lawn chair to hold a pair of 11x80 binoculars steady. The frame worked very well, though the lawn chair didn't adjust easily. Mike had some ideas for a better chair, however, and was planning how to fix it.

During the day, I had noticed an 8-inch Newtonian scope with an apodizing screen, so I looked up the owner (Darian Rachal) for a peek through it. Darian's mainly a planetary observer and so we looked at Saturn. I'd been agnostic regarding apodizing screens, but having looked through the scope with and without one, I admit I saw increased contrast in the cloud belts with the screen. The seeing was just as bad as last night, but with the screen I was able to trace the C ring across the ball of the planet and observed that the southern edge of the north equatorial belt was more sharply defined than the northern edge. These weren't as clearly seen without the screen.

I'm not sure how to account for the effect, though reducing the extreme contrast between black sky and bright planet must contribute a lot. (This is also why many planetary observers prefer to look during twilight.) I'm told that a neutral density filter held over the eyepiece works just as well, but I've yet to do a side-by-side test of both methods.

My next stop was at the corral field to visit the 13-inch Dobsonian owned by Lee Rubarth. He had a motorized collimating device for his telescope. Looking like two black pie plates attached rim-to-rim, it bolts to the rear hatch of the telescope. Inside the device, three servos (model airplane technology) screw the collimating bolts in or out under command from a small

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paddle held in the observer's hand at the eyepiece. This night, the change rate was set too high so I succeeded merely in zooming back and forth, overshooting and overcorrecting hopelessly. After Lee did a brief autopsy in the dark, I was given a rain check to try it again the next evening.

Dinner was now six hours past, so feeling weak, I paid a midnight visit to the red-lit all-night snack bar (coffee, soda, candy bars). Revived by a hefty jolt of caffeine and sucrose, I set up for another binocular session — this time with Tirion in hand. I confirmed my identifications of last night and did many more.

With the naked eye, I noticed the star cloud that sits right at 0° galactic latitude and longitude is distinctly brighter than the surrounding ones — appropriate! Moreover, if you stand with your head tilted to turn the Milky Way "horizontal," you get a strong impression of the nuclear bulge. It's a bit like observing NGC-4565 from very close up.

By 3:30, I figured the crowd at the computer-run 24-inch ought to have thinned somewhat. There were about five of us in line. As it swung from one object to the next, it first came up to the vertical, then rotated to the correct new azimuth, and finally dropped in elevation. The software kept track of how many turns it makes, so the cord doesn't wind around the azimuth shaft. What impressed me was that it would swing from one side of the sky to the other and finish with the new object within a 120x field of view — not the center of the field perhaps, but in there!

We looked at the standard objects — Jupiter, the Ring Nebula, Omega Centauri (how quickly the extraordinary becomes routine!), NGC-5128, M-51, M-27. I could not detect the central star of the Ring, but did see 13 stars in M-27. Another target was Abell 2151, a rich cluster of galaxies in Hercules. I could see several members, but not having a finder chart and being unfamiliar with the field, I have no idea which ones they were.

By about 4:30, I ran out of gas and tottered off to bed.

Wednesday was the first official day of the Star Party. By noon, there was some thin cirrus cloud drifting over. I didn't miss the sunshine too much — the (fried) back of my neck especially — but it didn't bode well for the coming night's observing.

I went into Ft. Davis with Ed Boutwell for lunch and visited the local bookstore (got Frank Dobie's *Tongues of the Monte*). Back at the ranch, I ran into Brian Skiff, a young astronomer from Lowell Observatory who was attending the Star Party to present a paper and see friends. We toured the area, noting the many more scopes which had arrived that day. At one point, we watched Ron Price unload his 12-inch f/15 Cassegrain, one of four scopes originally made for the U.S. Geological Survey. Brian had used one of the others in Flagstaff, and filled Ron in on what he knew of their history.

As the afternoon wore on, the clouds thickened. Despite the added numbers, dinner seemed rather subdued. Afterward, we filed into the "Prude Opry House" for the first night's invited talk. Dr. Tom Barnes, assistant director of McDonald Observatory, spoke on new advances in determining stellar radial velocities — motions directly toward or away from Earth. In the past, these studies have opened up the structure of our own Galaxy, and they now promise to uncover companion stars and planets belonging to the local stellar population. It's an exciting field, rejuvenated by instrumental advances that have lowered detection limits to about 10 times what they were 20 years ago.

Omega Centauri is one of those objects that seems to spill out of your eyepiece.

When he finished, we got the bad news: it was officially overcast. I went back to Walnut, which I was now sharing with some recent arrivals, and talked for a few hours to David Levy and Steve Edberg. David's an astronomer who works on asteroids at Kitt Peak, and Steve is the coordinator of amateur observations for the International Halley Watch at the Jet Propulsion Laboratory.

Thursday the 16th broke cloudy; it looked like rain had fallen during the night. After lunch, the activity overhead started getting interesting. Heavy storm clouds were passing at low altitude, some of them mammatiform — a feature found under actively-building thunderstorms. The western sky blackened and the rumble of thunder became louder and more continuous. With rain pouring down and lightning fingering the yellow hilltops, Steve Edberg was ecstatic: "Look," he said, after we'd been kidding him, "back home in L.A. you're lucky to see one of these a year!"

I missed the first paper of the afternoon session watching the storm, then hurried inside to catch the presentation by Jack Marling. He has been photographing faint planetary nebulae with a 24-inch telescope on Mauna Kea. Although his results can't be duplicated by most amateurs (no access to the equipment), his photos of these faint puffballs of gas were an inspiration to any observer.

Jack's talk was followed by one on a project that he and Bill Faatz have been doing for the past few years: monitoring light pollution. They have a 1P21 photomultiplier tube and three filters (5260 A, 5460 A, and 5577 A) to measure pollution from incandescent, mercury vapor, and oxygen (airglow) sources. They found that the Star Party site has half the incandescent pollution, one-tenth the mercury vapor pollution, and about the same airglow as their "reference" site at Digger Pines State Park, California. It appears the TSP has a super site — notwithstanding the thunder booms that periodically interrupted the talks.

In counterpoint to Faatz and Marling's talk, Klaus Brasch of Tulsa, Oklahoma, showed a series of astrophotos he'd taken from a light-polluted site. He has worked wonders with an old Celestron 10-inch, a telecompressor, and 3M 1000 film duplicated onto Ektachrome 64. Then Todd Hansen of the Riverside Telescope Makers' convention (which was meeting at Big Bear, California the week after the TSP) described the pioneering efforts of Henry Page Bailey, a Riverside amateur astronomer in the 1930s.

The last talk of the afternoon was by Houston amateur Lee Cain, whose 17½-inch Dobsonian binoculars have earned him great renown. Lee has since sold the binoculars to a friend who brought them to the TSP. I wasn't able to look through them Monday or Tuesday night, but had hopes if the weather ever cleared. Lee's talk focused on the question of why and how binocular viewing adds so much. He has been collaborating with Dr. Keith Bowen, an optometrist. The figure for improvement he'd come up with was 40% — in essence, it equals the square root of the number of eyes you look with. Or you could say that a single scope must have 20% more aperture to give the same effect as a given pair of binoculars.

When Lee's presentation ended, we all trooped out to check the weather. Thunder was still around, but long intervals of yellowy sunlight made the tree leaves glisten bright green. The air smelled clean and wet. Tiring of ranch food, I went with Chris Schur, Pierre Schwaar, and some Phoenix friends of theirs to the lodge restaurant in the nearby Davis Mountains State Park.

The evening speaker was Dr. Stephen Maran of Goddard Space Flight Center. He regaled us with dozens of slides and many uproarious anecdotes of what the "hot seat" felt

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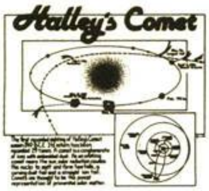

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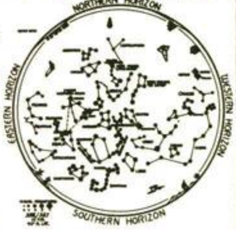

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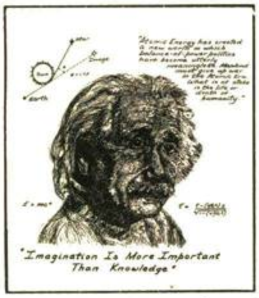
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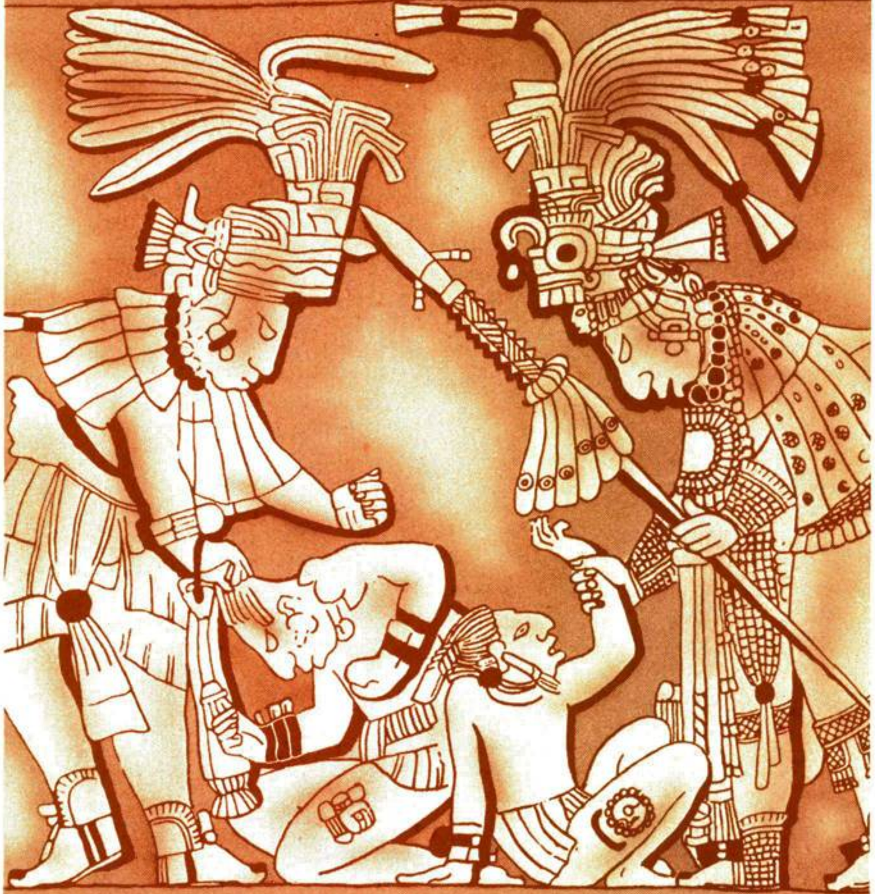

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like: back in '74, he'd been drafted into being NASA's "manager" for Comet Kohoutek!

Unfortunately, by the time the talk broke up, thick clouds were scudding by and observing was ruined for the night — again.

Friday, it turned out, was make-or-break day for a number of TSP'ers. Many, especially those who'd arrived on Wednesday, were discouraged by the continuing bad weather. When the afternoon forecasts didn't give much hope for the coming night, some started packing for home.

The paper session Friday afternoon, however, was quite good. Michael Rowley gave a talk on the problems of combating light pollution, particularly high-pressure sodium lighting. He lives in Clovis, New Mexico (pop. 31,000), a town dominated by the "booster" mentality at the civic level. The more lighting the better, so far as they're concerned. Michael said you have to get to know the utilities and expect a strong bias favoring lots of lights. He recommended that clubs trying to combat light pollution get in touch with David Crawford at Kitt Peak National Observatory (P.O. Box 26732, Tucson, AZ 85726) and call Dick Anderson at North American Philips, the company manufacturing low-pressure sodium lamps (213-637-7511). He finished by noting that Halley offered an excellent opportunity to raise public awareness of the problem.

Robert Reeves of San Antonio then spoke on spacecraft missions heading for Comet Halley. Information on these craft — the two Soviet Vega craft, the two Japanese probes, and the Europeans' Giotto — is rather hard to come by, perhaps because the national agencies who built and operate them don't have the same ready access to the U.S. media that NASA has. He did a fine job in half an hour, leaving the audience with a clear overview of a complex situation.

The next presentation was really a travelogue — Lee Cain and George Ellis (the Astronomical League's president) each gave a slide show on their forthcoming expeditions to South America to see Halley. Both their sites looked good — I'd be hard pressed to choose!

Chris Schur then gave a slide show featuring some wonderful astrophotographs he'd taken with 3M 1000 slide film pushed 1½ stops. He said the film is better than most people think, and the results he's gotten certainly back him up.

The last main item on the agenda was an open forum conducted by George Ellis. The topic was promoting astronomy during the return of Halley's Comet. George began by reminding us that the League has a speaker's bureau to arrange for guest lecturers at club meetings. Then other ideas surfaced from the audience: many state and national parks are delighted when amateur astronomers show up with telescopes. Given adequate warning, the rangers can publicize the "star show" and greatly increase turnout. The campers have a good time, learn a few constellations, and see some things they'd never see otherwise. Or do what one Oklahoma club did: they got an observatory built through the help of a local service club. Rotarians, Lions, Kiwanis — all are looking for community-oriented projects. Why not a public observatory?

The main message of the forum, however, was that while some of us may already be getting sick of hearing about Halley, public interest in the subject is only beginning to rise. Unless we're willing to play ostrich for the next year, each of us is going to be a "comet expert." Let's *use* the publicity. It could be the best thing that's happened to backyard observing since, well, 1910.

After dinner, the speaker was Steve Edberg of the International Halley Watch. In a talk which nicely dovetailed with Reeves' from the afternoon, Steve discussed what a comet is, what features they display, and what "strange animals" they are. He then described the Halley Watch and its activities, especially what amateurs can and are doing. With sky map graphics, he walked us through the entire apparition, pointing out when the Moon would interfere and where the best "home" observing sites would likely be. (The southwestern U.S. is tops overall — no surprises there.) When you see how high Halley will be from middle southern latitudes, however, you really want to pack your bags immediately!

After the talk broke up, the sky was cloudy with distant lightning flashes around the horizon. By now, however, I was totally unwilling just to say "phooey" and head for bed — and I'm very glad I didn't. Around midnight, the sky was mostly clear and very dark. But the air was so saturated with moisture that black clouds were constantly forming and dissipating at low altitude. If you could tolerate the heavy dew and were willing to switch targets as the clouds crawled by, it was an excellent night. The seeing was quite good — stars had sub-arc-second disks.

Unfortunately, it went relatively unappreciated: some observers had left, and among those whose scopes were still in place, many must have given up early for the scopes stayed wrapped. I found Pierre Schwaar's 20-inch in operation and looked at the Ring, M-51, and a small planetary in Scorpius (one of Jack Marling's little puffballs). After looking at Saturn full aperture, Pierre stopped the scope down to a 9-inch and we looked again. The view was about as good as what I'd gotten Tuesday night with Darian Rachal's apodized scope.

I then went over to a 17-inch Dobsonian belonging to Don Pierce of the Houston Astronomical Society. His was perhaps the best-collimated large scope I'd looked through all week. Earlier in the meeting, there had been a report of a supernova in M-51. It turned out to be erroneous, but gave everyone a good excuse for scrutinizing the galaxy, anyway. With Don's scope I saw five stars "in" M-51 and caught a hint of a luminous connection to NGC-5195, the small companion galaxy just to the north.

David Levy had his 8-inch comet seeker with him. He had been anxious during the past few days to check out — eliminate, really — the possibility that a faint blob he'd seen in Pegasus was a comet. After much scanning back and forth, and cursing a cloud that seemed to linger over the Great Square, he decided there wasn't any chance that it was a comet. We observed a few double stars and the Veil, both "naked eyepiece" and with a UHC filter. I noted once more that the NGC-6960 part of the Veil (near 52 Cyg) seems to float in front of the star. This 3-D effect is totally spurious, but I've never been able to shake the impression.

Running on stored energy from all the previous crummy nights, I was surprised to look at my watch and note the time was quarter to five! The Milky Way was past culmination, the Dipper nosing down to pass under Polaris, and even the Double Cluster in Perseus was high enough to look at. Finally, though, the damp got to me and I headed back to the cabin.

I'd set the alarm for 9 a.m. when I turned in because I didn't want to miss the swap meet, scheduled for Saturday morning. It was held outside the building housing the commercial displays. Few people were there when I arrived, but the crowd and pace picked up quickly. I saw everything from a junky 2-inch reflector (which had no takers at $10 and ended up being given away as a joke door-prize that night) to a whopping 135mm f/1.5 telephoto lens. Cameras, lenses, eyepieces, back issues of ASTRONOMY and *Sky & Telescope* — all sorts of stuff was up for sale. I also voted in the astrophoto contest, whose entries were arrayed on the mantle in the building — some of the best work, I noted, was done in black and white.

Hearing shouts and cheers, I went outside. There I spied a solemn procession led by George Ellis in a

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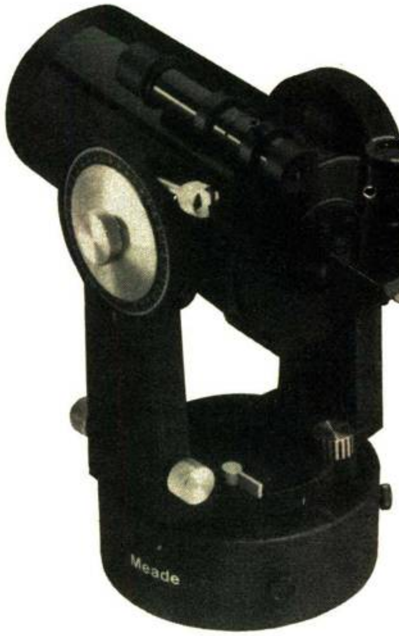

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blue wizard's gown and conical cap. They were carrying a "telescope" to be sacrificed to the cloud-deities of west Texas. Made of styrofoam coffee cups, tinfoil, and other kitchen hardware, the telescope had a (plastic) "fork" mounting. They placed the sacrifice on a rock, stood back to let the Wizard of Odds mutter the incantation, and then an acolyte stepped forward to ignite it with sunlight and a lens. Unfortunately, at that very moment a large cloud came over — oh, woeful omen! — and a somebody's Bic was flicked into service.

After the ceremony, it was time for the group picture. We trudged up the ridge to Boutwell's Folly and arrayed ourselves in front, slightly out of breath in the warm wind. Click, whirr; "One more, please!"; click, whirr. I looked up past a vulture searching for its lunch and rated the prospects of clear skies that night as only so-so. Fair-weather cumulus was sending patches of shade across the hills, but such clouds vanish at sunset. More worrisome were the thin sheets of altostratus higher up.

The after-lunch talks began with a picture show of photos taken earlier in the week by Robert Reeves using his portable tracking mount. This was followed by Brian Skiff's report on a curious star he's been investigating for the past few years: BM Scorpii, an irregular variable and the brightest star in the cluster M-6.

Billie Westergard of the Delaware Astronomical Society spoke next about his club's project for determining the colors of double stars. They photographed a standard Macbeth color chart in daylight on the first frame of a roll of Ektachrome 64, and then took photos of double stars on the rest of the roll. Comparing the color chart slide with the slides of star images, they found the film reproduced spectral types with remarkable fidelity. Tom Buchanan of Atlanta, Georgia, then described his homemade spectrograph, which uses an ordinary 35mm camera. The entire device was compact, portable, and produced fine, relatively detailed spectra of bright celestial objects.

The last speaker was Robert Reeves, who told us how he built his small portable tracking mount for astrophotography in the "boonies" — you'll find an account of the mounting in this month's Equipment Atlas.

After the session finished, I went with Chris Schur and Pierre Schwaar up to the windy football field to photograph their telescopes. I got the detail shots I wanted on Pierre's 20-inch, then did Chris' scope. He calls it "Trifid"; it's a 12½-inch f/5, finished in Hα red, and trimmed in blue (for the reflection nebula) and black (for the dust lanes). We unwrapped the scope, I took a few snapshots of him with it, and then a black rain squall came over. Pelted by cold wet gusts, we wrestled sheets of wildly flapping plastic over the two scopes and ran for cover ourselves. We heard later that quarter-inch hail had fallen about a mile away.

In the evening on the way down to dinner, I decided to take a last tour of the ranch since it would be dark when the talk ended. I found that Wednesday's thicket of telescopes had become pretty sparse. Many people, even those planning to stay the night, had already broken camp and packed their equipment away.

> ***If we don't get the children interested in astronomy, there'll be no next generation of astronomers.***

The Saturday night talk is in many ways the emotional centerpiece of a gathering like the Texas Star Party. It's a time for jokes, shared remembrances, and awards. It's also a time for saying goodbye — to friends you've known for years and those you met this week. There's a certain melancholy in such and this year's TSP had had no long string of perfect nights to sweeten it.

The observing awards and door prizes followed the evening talk, but for me the high point was the talk itself. David Levy was the speaker, his topic "Observing in the Shadow of Kitt Peak." It's hard to sum up an inspiring, funny, and moving talk, and it's impossible to convey the impact. It sounds trite, but you really had to be there. Starting with photos of the purple shadow of Kitt Peak reaching out across 60 miles of desert, David talked about the various "shadows" that Kitt Peak throws across astronomy.

The first was amusingly literal: since his house lies due east of the mountain, twice a year Kitt Peak's sunset shadow actually passes over it. Then, in a more sober note, he mentioned the next shadow: that of the professional over the amateur — the attitude that only professionals can contribute to science. Another "shadow" is light pollution: how long will even remote sites like Ft. Davis remain viable? And funding? "Everyday I get told Kitt Peak is going to have to shut down instruments." Yet another shadow lies across the future: the next generation.

Leaving us to meditate on these disquieting questions, David gave a wordless slide show of various observatories set to Bach's "Air on a G-string." With the lights back on, David then addressed his final "shadow": what amateurs have to give to the professionals. "We love to look at the stars — we don't need formal proposals or projects." he said. "We don't need to be successful, even. We just have to be there and ready when the sky throws you a hard ball." Far too many professional astronomers have lost that sense of wonder, of delight, he noted. How many of them still feel regret when morning twilight forces an end to observing?

The last part of David's talk returned to focus on children. "If we don't interest them, there'll *be* no next generation of astronomers. *Star Wars* and other science fiction movies haven't done it. There's probably no more real interest in observing today than when we were kids." He described a little play he puts on for elementary school classes. In it, Galileo, fresh from his discoveries of the jovian moons, confronts four men in long black robes. They offer him a choice: either deny that four moons circle Jupiter, or face torture. In the play Galileo sensibly recants, but says later that "someday, perhaps hundreds of years from now, children may be able to look through a telescope and see the moons I discovered." When the children in the class then go outside to look at those moons of Jupiter, there are no discipline problems, no pushing or shoving. The children know what they're about to see is important.

David finished by quoting famed amateur and comet hunter Leslie Peltier: "To hunt a speck of moving haze may seem a strange pursuit, but . . . in no better way can we come face to face, night after night, with such as wealth of riches as Croesus never dreamed of."

After the meeting dispersed, several of us went back to Walnut cabin where an impromptu party gathered. David Levy was there, receiving well-deserved congratulations in his slightly embarrassed way, while many people drifted in and out as the evening wore on.

Later, I walked outside onto the red-lit porch, felt my eyes begin to adapt in the gloom, and eventually looked up. It had grown chilly and the sky wasn't very clear. Walking down by the main gate, I saw through gauzy clouds the Milky Way lifting over the hills to the east and Leo balanced on one forepaw in the west. A thought I'd heard in the talk kept coming back, stubbornly. "We amateurs observe the sky because it's the most rewarding activity we know."

— Robert Burnham

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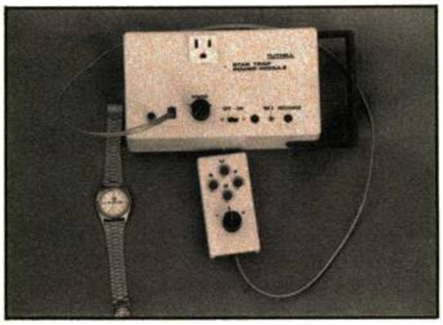

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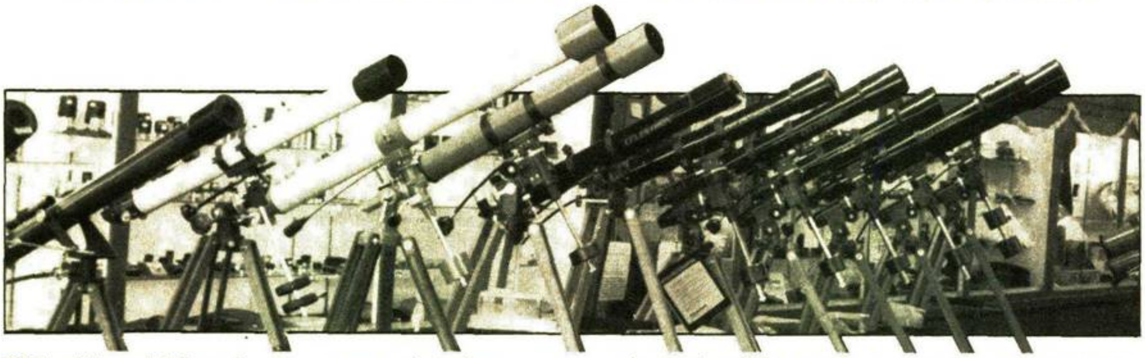

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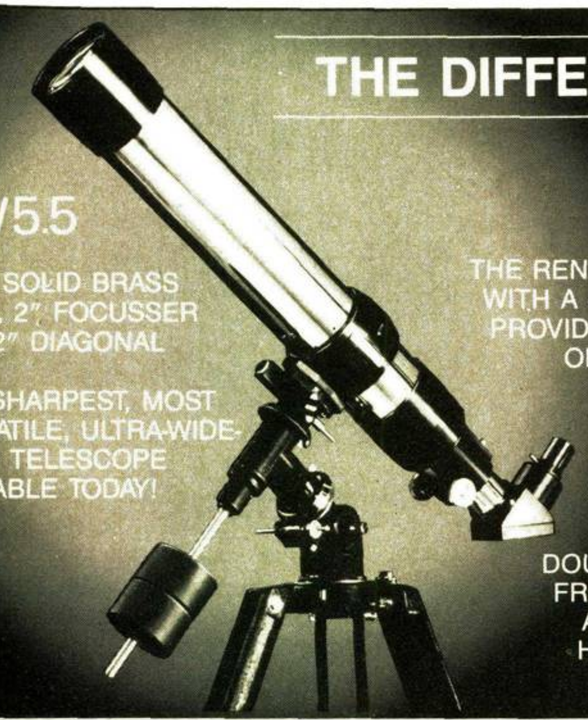

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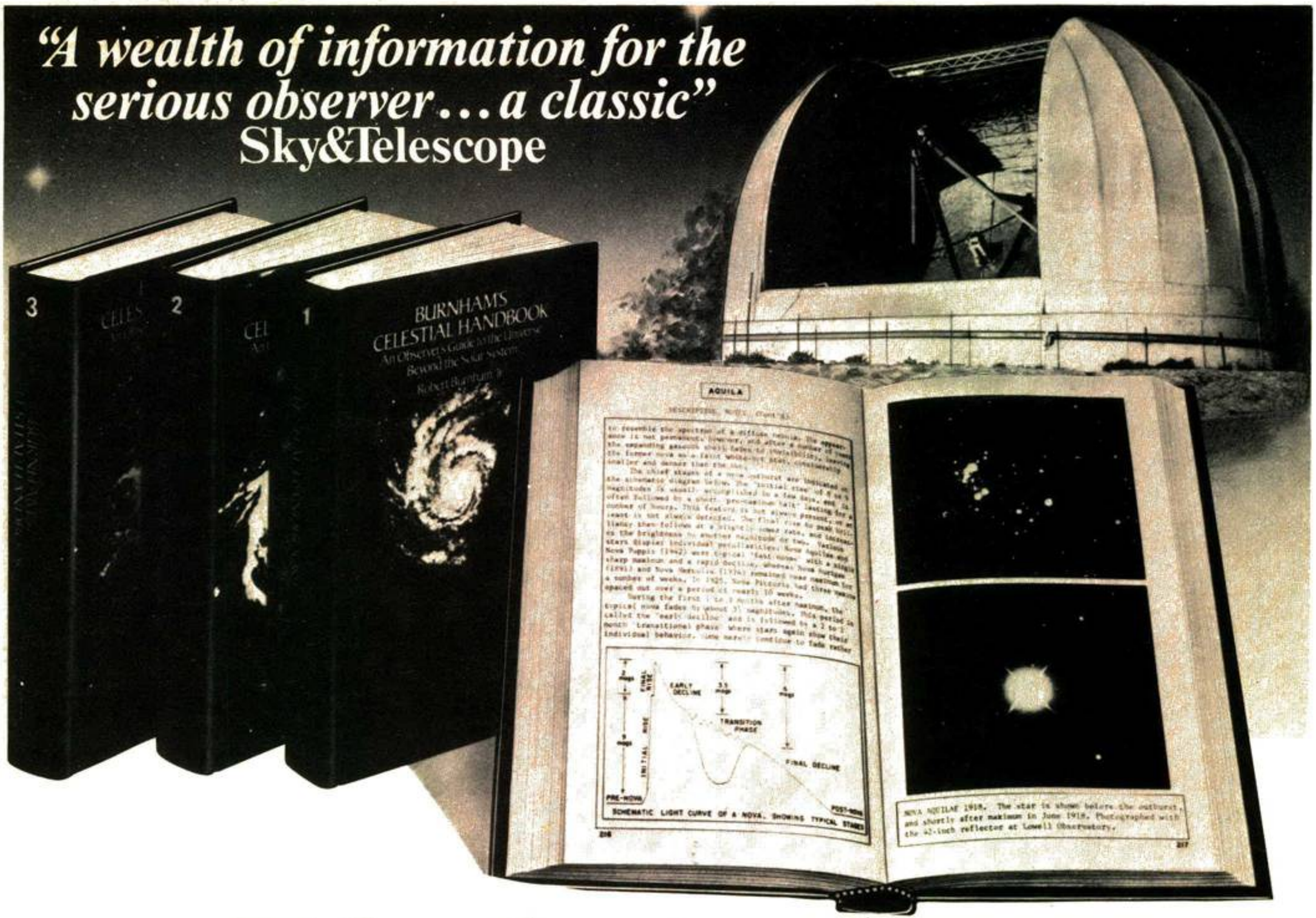
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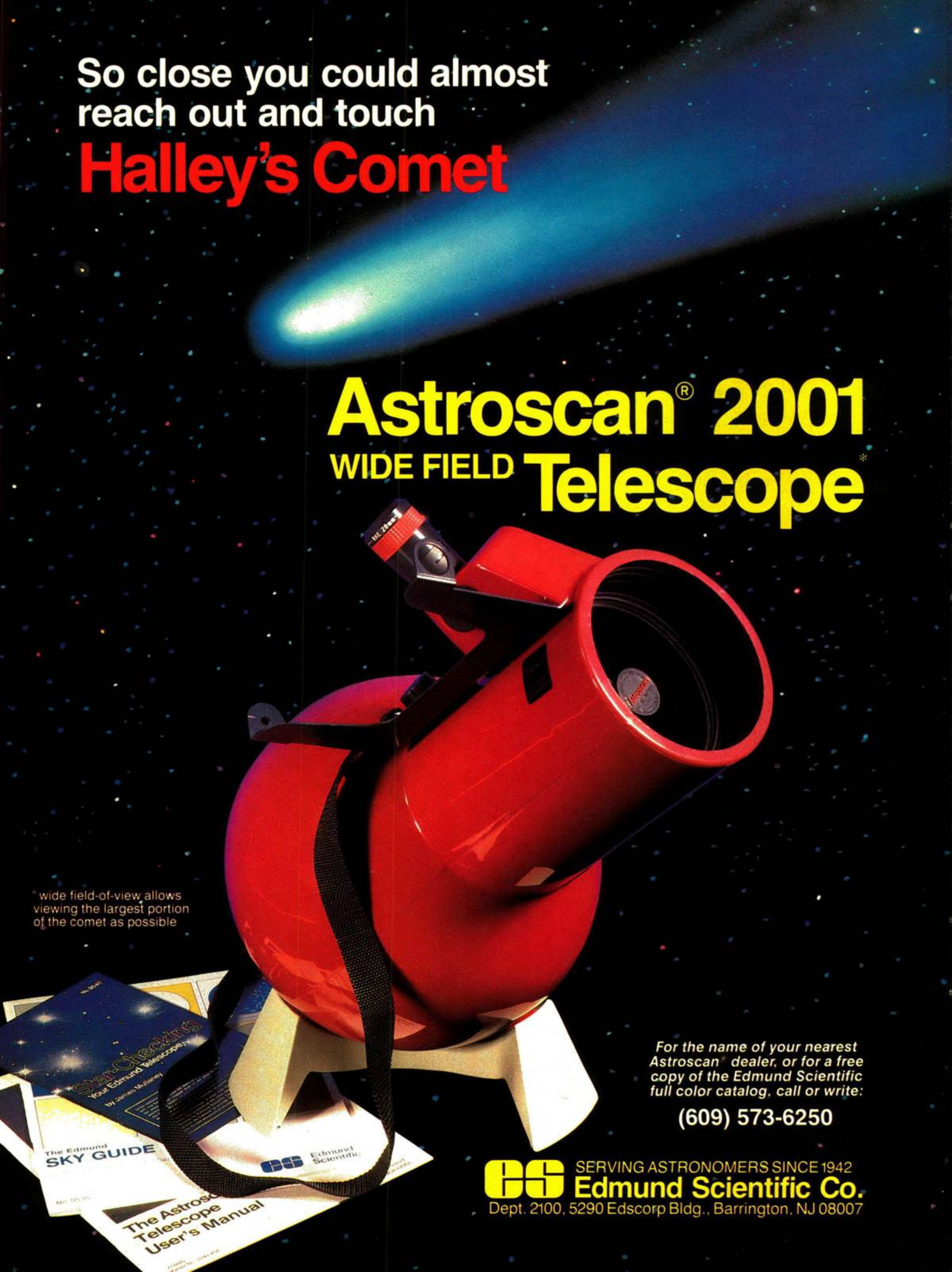
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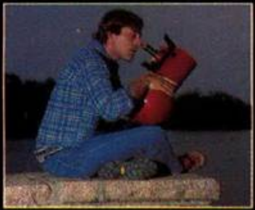

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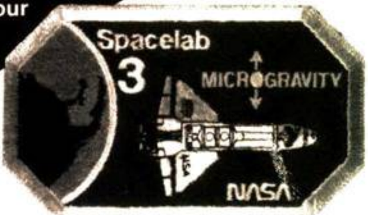

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ASTRONOMY

In Focus

Halley Time Capsule

Sir / I await my first sighting of Halley's Comet with great excitement. Our observatory was dedicated to the memory of Edmond Halley and is equipped with a 16-inch Newtonian scope (invented by Halley's friend, Sir Isaac Newton).

At the 1986 Texas Star Party next April or May, we intend to seal and bury a time capsule at the Edmund Halley Observatory on the Prude Ranch in Ft. Davis, Texas (the site of the star party). The capsule will bear instructions to open it during the comet's next appearance.

This could be a very exciting project. Any readers who would like to submit relevant materials for inclusion in our (small!) capsule can contact me by sending a self-addressed stamped envelope to:

Edmund Halley Observatory
c/o Ed Boutwell
720 S. 23rd St.
Birmingham, AL 35233

Lost in the Stars

Sir / July's "Best Astro-Photo" is even better than your caption writer thought. In addition to Jupiter and the Lagoon and Trifid Nebulae, it also shows Neptune! Neptune is in the upper right quarter of the photo, 2.8 inches from the right edge and 3 inches from the top of the page. It forms a nearly right triangle with two stars to the right of and slightly above the Lagoon.

Thomas M. Faber
Hampton, GA

The Case *Against* Mars

Sir / As a space advocate, I'm terrified to see other space advocates proposing manned landings and occupations of Mars as our next major goal — as in "The First Colony on Mars" by Michael Carroll (June 1985 issue).

There might be life on Mars! Contrary to popular opinion, the Viking landers didn't rule that out. What they did show is that *something* goes on in the martian soil, which is either life unlike any we know on Earth or pre-life chemical processes that mimic Earth's in some ways and might give us clues about how life started here.

Either way, land humans on Mars just once and you've forever contaminated that planet with Earth bacteria — some of which, lab experiments show, can live there. There's no way present technology can totally sterilize a manned spacecraft, let alone humans in spacesuits, without killing the people too. The Viking landers were sterilized by heating above the boiling point of water for two days.

By all means, let's send manned spacecraft to *orbit* Mars which can then send down sterilized unmanned probes *repeatedly* so that surprises like those the Viking landers revealed can be immediately investigated.

But please don't contaminate the one place in the Solar System where we know Earth-type life can exist until we know for sure whether any life exists there.

And by the way — even politicians who recognize the importance of space issues so infrequently managed to notice this one — there's an international treaty, currently in force, against contaminating Mars with Earth life. A manned Mars landing, let alone a base there, would violate it.

Jim Loudon
Ann Arbor, MI

Missing Evidence

Sir / I was surprised to see in the article "Are Quasars Far Away," October 1984, that while much mention was made of examples that cast doubt on cosmological distances for quasars, one of the most conclusive pieces of evidence for these distances was completely ignored.

I refer to the "twin" quasars 0957+561 A,B that have been determined not to be twins at all, but two images of the same object produced by the action of a gravitational lens (*Scientific American*, November 1980, Vol. 243, No. 5, pages 70-78). The quasar shows a redshift of 1.7, while the deflecting cluster of galaxies shows a redshift of .4, indicating extreme distances in both cases.

Since that time, a number of other likely gravitational lenses have been discovered, all involving quasars at very great distances. Because of the geometry required for these effects, the quasars must be as far away as their redshifts would imply.

Bob Parker
Bozeman, MT

BAA Satellite Predictions

Sir / L. Michael Poda (In Focus, May 1985) is wrong about the artificial satellite section of the British Astronomical Association. Not at all defunct, we are still a source of tracking data and identifying satellites.

Mr. Poda is also incorrect about the present status of Pageos, which has broken up on a number of occasions — the most impressive being in January 1975, when hundreds of fragments created a sparkling procession tracking slowly across the night sky. This procession was visible for many successive nights. (It was the most exciting celestial sighting I've ever seen.) Even today, there are about a dozen fragments of Pageos still orbiting the Earth. Probably the brightest of these is designated 1966-56G.

The second Spacelab mission was *not* visible over Europe for although it passed over Europe, it did so during daylight. The small "Get Away Special" satellite launched from the Shuttle during the mission is about to become visible, as orbital precession brings its near overhead transits into nighttime hours.

Larry Sessions says in his article ("How to Observe Satellites," June 1984) that to find out anything about a satellite spotted passing through the evening sky, it's necessary to observe the satellite on two separate passes. That's not true. It's possible to identify a satellite from two or more accurately timed position observations taken during one transit — you can also accurately measure its angular velocity by dividing the angular path by the time taken. We've used the technique in identifying thousands of unexpected satellites seen in the past 27 years.

Russell D. Eberst
Assistant Director
Artificial Satellite Section
British Astronomical Association
London, England

Sir / Although the prediction service provided by the Artificial Satellite Section of the BAA did not function for about two years due to lack of funds, the prediction service restarted last autumn.

It is principally designed for training observers. The service covers objects brighter than magnitude +6 that are visible during the evening visibility period as seen from northwestern Europe.

Each potential observer is provided the necessary charts and tables with full instructions on how to make observations. When observers have reached the required degree of accuracy, their names are forwarded to the national prediction center at the University of Aston in Birmingham. They are then placed on the list of observers who receive general predictions.

Howard Miles
Director
Artificial Satellite Section
British Astronomical Association
London, England

The Star Board

Sir / The Denver Astronomical Society has just started a computer bulletin board service for amateur astronomers. The "Star Board" is accessible 24 hours a day free of charge except for the phone company's long-distance billing, and supports 300 or 1200 baud.

For a trial run, phone the access number at (303) 455-3113. At the FIRST and LAST NAME prompts, enter "ASTRONOMY" and "MAGAZINE"; for the password, enter "dasbbs"; then from the main menu, type "M" for the message board. From the message board, type "5" for the astronomy board. From there, you may browse to your heart's content. If you like what you see, log on your own name and password the next time you call.

Brian Rickard
Assistant Director
Chamberlin Observatory

Remembering the Dipper

Sir / In May's Eye on the Sky, Fred Schaaf asked for "a good mnemonic device" for getting the Big Dipper's stars in their correct order. Because six of the names begin with "A" or "M," such a mnemonic device pretty much has to include the whole first syllable of the name, if possible.

My best is as follows:
Alcoholic misers alienate Megan.
Feckless Meredith is dubious.
(Alkaid) (Mizar) (Alioth) (Megrez)
(Phecda) (Merak) (Dubhe).

Although it may not become as well known as "Oh Be A Fine Girl, Kiss Me" (stars' spectral types), I hope this helps observers remember the Dipper's stars.

John Llewellyn James
Bellwood, IL

Thanks to the Planetary Society

Sir / After seeing my article "The First Colony On Mars" in the June 1985 issue, I suddenly realized I left out something very important.

"The Case for Mars" and "The Case for Mars II" conferences were supported by, funded by, and would not have happened without the Planetary Society. The society has for many years been the only financial supporter of many Mars studies. We owe thanks in large measure to them for the fact that people in official positions are talking about going back to Mars again. After many years of silence, the subject is no longer taboo.

Michael W. Carroll
San Diego, CA

Behind the Scenes

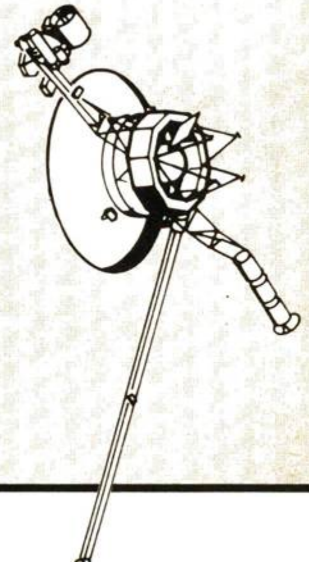
Amid the Halley Hoopla

In the midst of the Halley hoopla, we may be inclined to forget that there are still plenty of other things going on — events that, in the long run, may be considerably more interesting than Halley. This month's feature article highlights one such event: the Voyager 2 flyby of Uranus. On January 24, 1986, in the space of a few short hours, Voyager's cameras, spectrometers, particle detectors, and magnetometers will gather a wealth of information about the cold, green giant planet.

And this month, there's another virtually unheralded event — the first-ever flyby of a comet. On the 11th, NASA's International Comet Explorer (ICE) spacecraft will encounter Comet Giacobini-Zinner. Although the ICE mission can't compare to the American Halley flyby mission NASA *didn't* fly, it is still a first — and the data ICE obtains will support the Russian, European, and Japanese missions to Halley.

Amid the talk of Space Shuttle missions and encounters with planets and comets, we may overlook the simpler pleasures of Earth-based stargazing. Last spring, ASTRONOMY's Robert Burnham traveled to the Texas Star Party and in this issue writes about his terrestrial encounters with astronomers, telescopes, and Texas hospitality.

But in the end, you can't avoid Halley hoopla. If you're planning on traveling to distant parts of our planet next spring to see and photograph Halley, don't miss the do-it-yourself globetrotter's astrophoto rig in Equipment Atlas, beginning on page 57.



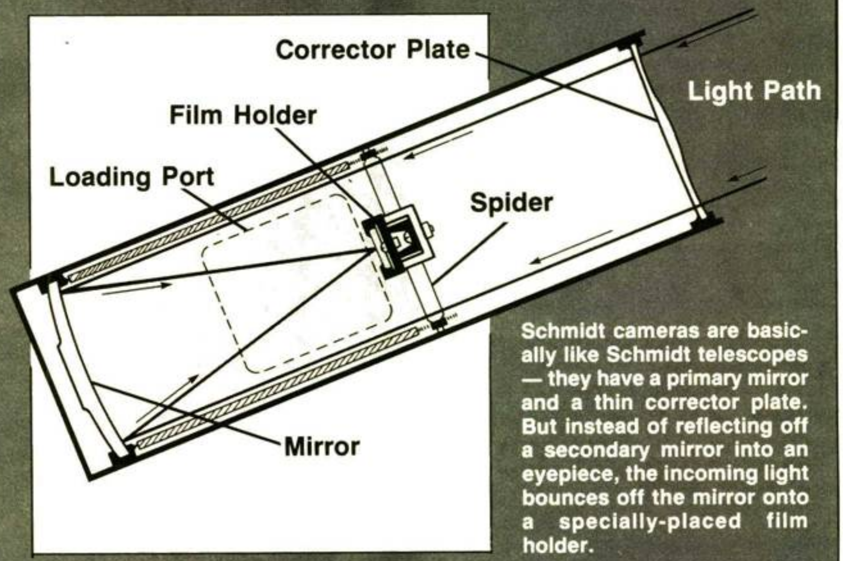
Sincerely,

Richard Berry

Richard Berry
Editor-in-Chief

Getting Started with a Schmidt Camera

by
Rick Dilsizian



Schmidt cameras are basically like Schmidt telescopes — they have a primary mirror and a thin corrector plate. But instead of reflecting off a secondary mirror into an eyepiece, the incoming light bounces off the mirror onto a specially-placed film holder.

It's four in the morning, your mind is partially shut down, and you're cold as can be. You've just spent 50 minutes outside trying to photograph the Orion Nebula, followed by 20 minutes inside trying to develop the negative. So what if it's ruined because the stars look like doughnuts? Well, join the ranks of hundreds of frustrated would-be astrophotographers — welcome to the cold, unforgiving world. Or take a more peaceful alternative — get a Schmidt camera!

"What *is* a Schmidt camera," you ask? Simply put, a Schmidt camera looks something like a telescope at first glance — but has no focusing mechanism and no eyepiece. Instead of focusing incoming light onto a secondary mirror and then back to an eyepiece, the Schmidt simply focuses light onto an internal film holder located inside. You can't look through a Schmidt, but you can take stunning wide-field photos of the sky.

The Schmidt camera was invented by the German optician Bernhard Schmidt in the early 1930s. In an effort to minimize aberrations normally found in wide-field cameras, he employed a spherically-figured primary mirror, a specially-shaped corrector plate, and a film holder with a curved focal plane. Soon after Schmidt's first use of the camera, professional astronomers recognized its great value to research. In 1949, astronomers at Palomar Observatory began the now famous Palomar *Sky Survey* using a 48-inch Schmidt camera, and during the following decade they recorded the entire northern sky in red and blue light. During the 1960s, ingenious telescope makers and a commercial firm began producing these cameras, and Schmidt camera photography entered a new era.

Pros and Cons

Schmidt cameras are powerful tools for astrophotography. But before you think owning one will answer all of your needs, read on. The Schmidt camera has pros and cons you should be aware of.

On the positive side, Schmidt cameras can record large areas of sky in relatively brief exposures. Their great speed enables you to make exposures lasting only minutes — normally between 2 and 20 depending on how dark the sky is and how fast your film. Ordinary telescopes, with focal ratios 3 to 10 times greater, require longer exposures to capture the same amount of light. Because of the large amount of sky covered, guiding is less critical than with telescopic systems; you can get away with occasional brief glitches in keeping a guide star centered.

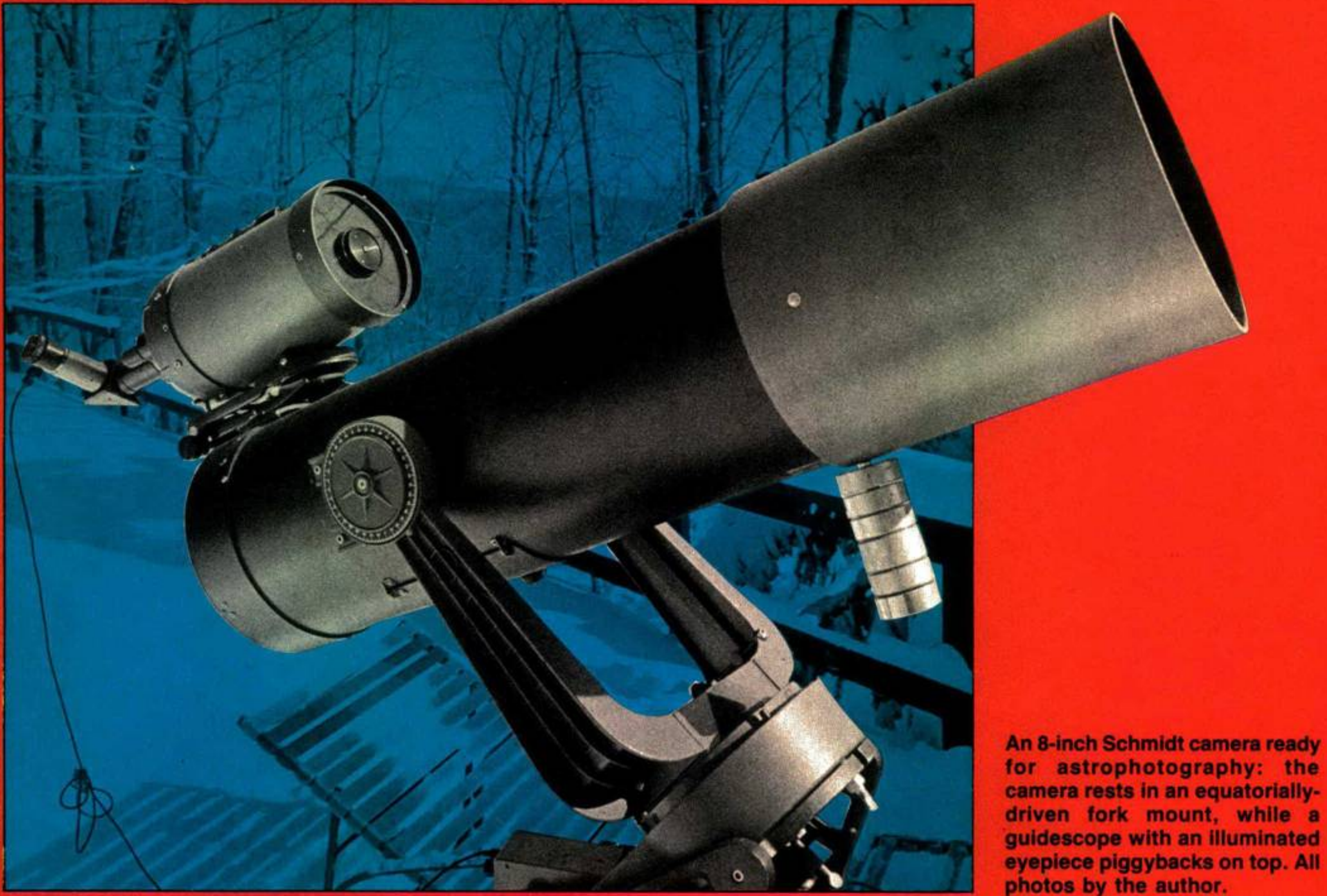
A second advantage is that once it's built and tested, a Schmidt camera doesn't need to be focused. For those accustomed to telescopic photography where focusing is such an integral and painful part of the set-up operation, the fact that Schmidt cameras eliminate this step is very attractive.

With all this going for it, how can the Schmidt have anything going against it? Well, first of all, the Schmidt camera is hopeless for photographing small objects such as planetary nebulae and most galaxies. The image scale just isn't great enough to provide satisfying results, even if you use fine-grain film and greatly enlarge the negative. Schmidt cameras are, by nature, recorders of only the largest objects in the sky. Second, forget about lunar and planetary photography. The Schmidt's image scale and photographic speed both work against it.

The Schmidt camera's forte is large but faint deep-sky objects and comets. If you understand and work *with* the limitations of a Schmidt, they can perform magnificently.

Step One: The Exposure

My camera is a Celestron 8-inch f/1.5 model, which I mount on a field tripod equipped with a tracking platform and fork. The following instructions for how to use a Schmidt are based on the



An 8-inch Schmidt camera ready for astrophotography: the camera rests in an equatorially-driven fork mount, while a guidescope with an illuminated eyepiece piggybacks on top. All photos by the author.

Celestron model, although they're applicable to any Schmidt — commercial or homebuilt. After the camera is mounted, I attach a 5-inch f/10 Schmidt-Cassegrain scope atop it for guiding. The 5-inch has a 12mm eyepiece with an illuminated reticle, which gives me a magnification of about 100x. Celestron also offers a 5.5-inch f/1.65 Schmidt camera, which mounts on top of the standard 8-inch SCT, and Meade Instruments manufactures a 4-inch f/2.64 Schmidt. Celestron and Meade offer the only commercially-made Schmidts in the United States.

Since Schmidt cameras usually ride piggyback on another telescope (or *vice versa*), setting up is pretty much like preparing for any guided astrophotograph. You needn't worry about focusing, because the Schmidt has a fixed focus. If there is a problem, it will probably be caused by the collimating screws that govern the corrector plate — and you'll have to send the camera back to the manufacturer for servicing.

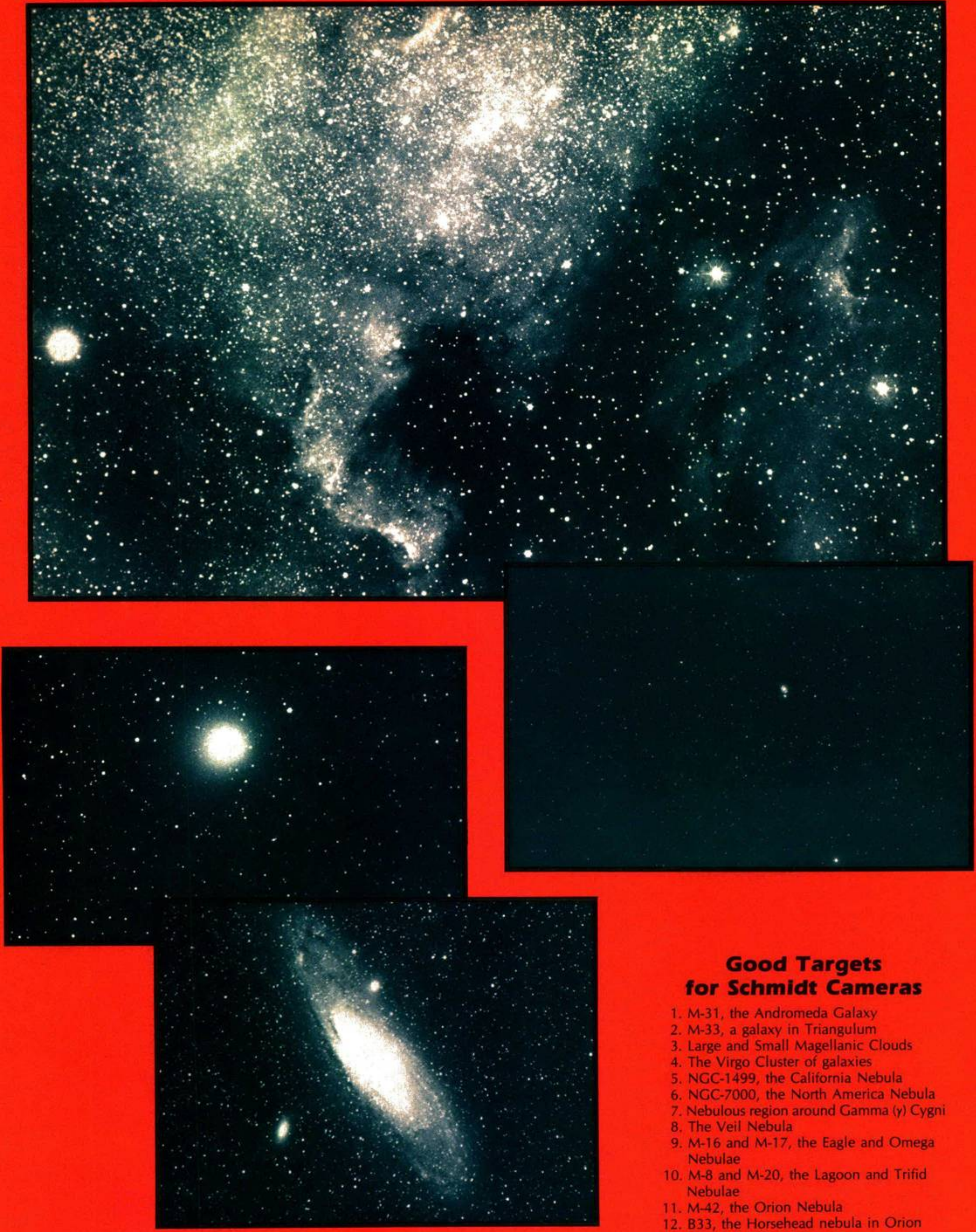
The next step after setting up outside is to polar align the mounting and make sure the drive is operating correctly (see "Easy Steps to Perfect Polar Alignment," ASTRONOMY, August 1982). Once this is done, go indoors to a dark room. (You can use a changing-bag in a pinch.) Then, using the Schmidt film holder and working in total darkness, cut a short length of film and insert it into the holder, *emulsion side up*. Be very careful not to scratch the film — or fingerprint it — when loading. When it is securely in the holder, tighten the retaining screw on the film holder and cover the emulsion side with a cover. (The commercial manufacturers supply a metal cover for this purpose.) Now you have a single frame of film ready to expose in the camera. Place the film holder in a light-proof container, such as a developing tank or a bulk film storage box, and transport it out to your waiting camera.

When you get to the camera, open the camera's side door — make sure the cover on the film holder is secure — and place the holder inside the camera until it magnetically "clicks" into place. Check that the front end of the Schmidt is covered, then remove the film holder's cap through the side port and close the port. Don't dawdle while you do this and keep all stray light out of the camera's interior once you've uncovered the holder. (Drape a large piece of black cloth over the camera and yourself if necessary.) When the side port is closed and secured, you're ready to go.

Once "up and running," the problem shifts to finding an object to photograph. This isn't as easy as it sounds, especially when you can't count on *seeing* the object you're trying to photograph. From even moderately light-polluted skies, many objects are just barely visible. The best procedure is to use the setting circles to find the approximate area you wish to photograph. Using a reference such as Tirion's *Sky Atlas 2000.0* or Vehrenberg's *Atlas of Deep Sky Splendors*, you should be able to locate a recognizable star pattern nearby. From that, you'll know right where the object lies.

Next find the reference star with the guidescope. This may take a little time — if the 12mm eyepiece gives too high a power, try a 28mm first and then switch back. Once you find the star, align the crosshairs in the guiding eyepiece to match the axes of right ascension and declination. This will make it easier to guide (see "Guiding," December 1980 issue). To find east and west, shut off the telescope's drive. Let the star drift and rotate the crosshair eyepiece until the star just slides along one of the hairs. This defines right ascension.

You're now set up and have a deep-sky object in mind to photograph, with a suitably bright guide star centered in the guide telescope. At this point, you'll face a disturbing fact: the Schmidt camera doesn't have a shutter. Instead, you'll have to place something opaque — such as a



Left: Comet West in 1976 photographed with an 8-inch Schmidt. Clockwise, from top: The North America Nebula; M-51, the Whirlpool Galaxy, shown at full frame; M-31, the Andromeda Galaxy; and 1983's Comet IRAS-Araki-Alcock.

Good Targets for Schmidt Cameras

1. M-31, the Andromeda Galaxy
2. M-33, a galaxy in Triangulum
3. Large and Small Magellanic Clouds
4. The Virgo Cluster of galaxies
5. NGC-1499, the California Nebula
6. NGC-7000, the North America Nebula
7. Nebulous region around Gamma (γ) Cygni
8. The Veil Nebula
9. M-16 and M-17, the Eagle and Omega Nebulae
10. M-8 and M-20, the Lagoon and Trifid Nebulae
11. M-42, the Orion Nebula
12. B33, the Horsehead nebula in Orion
13. M-45, the Pleiades
14. The Hyades
15. The Scutum and Sagittarius star clouds
16. The Double Cluster in Perseus
17. Any bright comet

Although Schmidt cameras cover large areas of sky, it's essential to guide with high precision. This 5-inch guidescope is equipped with an illuminated-reticle 12mm eyepiece.

To start and end Schmidt exposures, it's necessary to uncover and cover the corrector plate with a large opaque object — this is the only "shutter" the camera has.

large can covered with thick black cloth fitted on a long pole — over the end of the camera's tube before loading the film. After exposing it, you must place the cover back in front of the camera. This prevents light from entering the camera and fogging the film chip. Using a 5.5-inch Schmidt is essentially a one-person operation. But I've found that two people are needed for an 8-inch camera. One person inevitably jiggles both the camera and guidescope when removing the "shutter" for an exposure.

Schmidt Camera Photography in ASTRONOMY

"A Darkroom for Astrophotography," September 1980.

"An Inexpensive Roll Film Holder for Schmidt Cameras," February 1984.

"Getting the Correct Exposure," June 1981.

"Getting the Most From Your Deep-Sky Negatives," October 1980.

"Guiding," December 1980.

"How to Reduce Tracking Error," February 1982.

"Making Black and White Slides," May 1982.

"Processing Your Astronegative," November 1980.

"Simple and Inexpensive Tricolor Photography," November 1983.

"Successful Schmidt Camera Photography," December 1984.

"The 2415 Revolution," March 1982.

"Wide-Field Sky Photography," January 1980.

Incidentally, a few accessories help immensely. First, a dew cap prevents the corrector plate from collecting moisture which can quickly ruin an exposure by making star images go mushy; a dew cap also minimizes stray light that might reflect into the tube. Second, a polar-axis finder — an optical peepsight allowing you to zoom in on the north celestial pole rapidly — is handy. Third, I've found that electronic slow motion controls for both axes are very important.

Step Two: Developing

Once you've made an exposure, the work isn't over — you still have to process it. Years of darkroom work have convinced me that the best combination for Schmidt photography is TP 2415 film developed in the following way: using a 1:1 combination of Ethol UFG and D-19, develop the exposed film for 6 minutes at 70°F. Then rinse the film in water — acid stop bath is too harsh — to stop the development and fix in a standard bath for 2 to 4 minutes (see "A Darkroom for Astrophotography," September 1980, and "Processing Your Astronegatives," November 1980 issues).

Develop the film chips just as you would a roll of film, but be careful when placing them on the developing spool or they may contact each other during development and become ruined. Agitate *very* gently.

For enlarging, I use Agfa grade #6 Brovira Speed resin-coated paper. It has the highest contrast of any resin-coated paper currently on the market. I like getting high contrast prints, but you may prefer to use a lower contrast paper, say #4 or #3.

For color work, you can use either color slide film or color negative film. In 1977, I began processing color slide film as a negative. This yields pronounced color saturation and contrast. Processing film such as Fujichrome 100 or 400 through C-41 chemistry is the best route if you do color printing; then you'll be able to get a black (not red, green, blue, or yellow) sky. But be warned: it won't be easy.

Schmidt cameras are specialized and complex instruments. They demand much of their users, and require careful handling and much patience for success. But using a Schmidt camera for recording deep-sky objects is clearly possible: for proof of this, simply look at the Schmidt photos that have appeared in ASTRONOMY over the past 10 years!

Rick Dilsizian is an accomplished astrophotographer whose photos have appeared often in ASTRONOMY. By day, he teaches at Westchester Community College in Valhalla, New York.

ASTRONOMY
Reviews

Stars of Jade
Julius D.W. Staal
204 pages, paperback, $19.95
Writ Press (1984)
[Publisher's address: P.O. Drawer R, Decatur, GA 30031-2244]

"*Stars of Jade* is written for the reader and student of history and ancient astronomy, who wishes to know something of Chinese astronomy and lore." The present volume is basically a translation, update, and rearrangement of a work originally published in 1875 by the Dutch sinologist Gustave Schlegel, called *Uranographie chinoise*.

The Sun
Center for Aerospace Education,
Drew University
12" video disk, $320
Video Vision Associates (1984)

Remember when showing a film in class meant dealing with torn sprocket holes, broken splices, and not being able to get the footage you wanted? Laser video disks are bringing those days to a close. These iridescent shiny disks, resembling an audio compact disk but the size of an ordinary LP record, are read by a laser which can play the disks repeatedly without wearing them out. Furthermore, the disks can store sound as well as video images and are capable of playing the video forward or backward at slow or fast speed — and you can even stop the action altogether and step forward frame by frame. Try that on your home Betamax! Moreover, the picture quality is as good or better than that on 1-inch video tape, the national standard for broadcasting.

Regarding the disks as huge visual libraries that hold 54,000 still frames per side, Video Vision is publishing disks that are compendia of the Apollo and Shuttle programs, the Voyager missions, and, most recently, the Sun.

The Sun compiles the best still shots and short video clips of its namesake, taken by the major solar observatories in the United States. Contributors include Big Bear, Mt. Wilson, Kitt Peak, and Sacramento Peak Observatories, as well as NASA with material from its Skylab and Solar Max programs. Much of this footage, previously unavailable to classroom teachers, was compiled specifically for this disk.

The images on *The Sun* are excellent and varied. Included are dramatic time-lapse videos of solar prominences and flares, sequences that show differential solar rotation, the record of a complete sunspot cycle, and a you-are-there trip to a solar eclipse.

For any classroom teacher whose work deals extensively with the Sun on a level from upper elementary through college, the disk is packed with valuable information. The laser disk's interactive capability makes it possible to compare different types of prominences or to step through the eruption of a solar flare frame by frame. One warning: although Video Vision provides a detailed listing of the images and movie sequences, they assume you know and understand the significance of what you're seeing. This is not an astronomy text or even an AV workbook — nor is it a lesson plan. It's a *visual library*. Anyone who has to ask "What's the Main Sequence?" won't get much further than marveling at the pictures for their own sake.

The $320 price tag may seem stiff — especially when schools and colleges (probably the chief market for these disks) are cutting budgets. But compared to an equivalent amount of film, the price is not outrageous. Many of the sequences are otherwise unavailable on film and, unlike film or video tape, laser disks can be played over and over with no detectable wear.

The flip side of *The Sun* contains the 1976 film "The Universe" narrated by William Shatner, of *Star Trek* fame. While it is generally a good introduction to astronomy, the section on the solar system is badly outdated. Fortunately, laser disks let you pick and choose the sections you want to play. And Video Vision offers a more up-to-date view of the solar system system on their disk about the Voyager encounters with Jupiter and Saturn.

The Sun includes a "filmstrip" called "The Space Science Lecture Series," for which Video Vision promises software shortly. Also on the disk is a series of Landsat images of Canada. Documentation is not included, but can be had for the price of a postcard request. *Kathleen Hedges*.

A Decade of Comets
Don Machholz
111 pages, paperback, $8
Published by the author (1985)
[Publisher's address: 5234 Camden Ave., San Jose, CA 95124]

Between the start of 1975 and end of 1984, amateur astronomers discovered 33 comets — 38% of all those found in that period. In each of these years, on average, professional astronomers found 5.4 comets, while amateurs found 3.3. Don Machholz, an amateur astronomer and comet discoverer (1978 XIII), discusses when each comet was found, its observing circumstances, and other basic information (period, orbital elements, etc.). He then examines the statistics on these discoveries and compares them to comets found or recovered by professionals during 1975-1984. He also ranks each discovery by how long each observer had to search before finding the comet — Machholz himself comes in last, with over 1700 hours!

The Astronomical Scrapbook
Joseph Ashbrook
468 pages, hardcover, $19.95
Cambridge University Press (1984)

For 23 years, Joseph Ashbrook delighted thousands of astronomy buffs with fascinating, amusing, and certainly unusual little-known facts of astronomical history served up in his bimonthly *Sky & Telescope* column, "The Astronomical Scrapbook." Started in August 1954, the column ran until Joe's untimely death in August 1980.

Although he received his doctorate in astronomy from Harvard in 1947, Joe once confided to me that he would have equally preferred it in history. Now, 91 of his best articles have been carefully selected and brought together in 83 "mini-chapters," most no longer than two or three pages.

The book is divided into seven sections: "Star-Crossed Lives," "Telescopes and Techniques," Phenomena of the Earth, Moon, and Planets," "Studies and Students of the Moon," "Planets and Other Solar System Objects," Stars and Stellar Systems," and "Star Atlases and Other Publications." There is virtually something for everyone's taste in this book.

Although many of the original articles have been severely cut, the editor has managed to convey Joe's curiosity, integrity, scholarship, and fine style. In some cases, new information has been added that became available only after the original articles were published. The text is augmented with new and unusual photographs that didn't appear in the original articles. Even if you have a complete set of *S & T*, you'll find this book a welcome addition.

The Astronomical Scrapbook clearly brings to light Joe Ashbrook's skill as a detective, particularly in the book's final chapter, "An Enigmatic Astronomical Woodcut." Amateur astronomers are the focus of many chapters, and elsewhere we catch glimpses of the bizarre, even pathological, figures that have drifted through astronomy over the years.

One welcome chapter discusses "Some Invisible Astronomers" — the behind-the-scenes night assistants who were the silent and unpublished partners of many famous astronomers. Ashbrook: "Because such people seldom appear in printed records, [these] invisible astronomers are soon forgotten." Yet no reader is likely to forget the delightful photo of Henry Sawyer, arms buried in a dark-cloth as he changes plates on a 16-inch at Harvard Observatory, with a stogie firmly clamped in his mouth!

Students of the history of astronomy will find the chapters painfully short. The editor seems to have anticipated this and was careful to include 15 pages of citations to original literature at the back of the book. Though far from complete, they provide the serious reader with valuable sources for further reading.

Here and there I found a few inconsistencies which mightn't concern the casual reader, but certainly would confuse a student using this material as the basis for a paper. For example, on page 21 in Chapter 6, "The Crucial Years of Wilhelm Struve," this statement appears: "Carrying a Danish passport and a letter of recommendation, he [Struve] left Altona on July 6, 1808, and after a 35 day journey over poor roads of war-ravaged Prussia and the Baltic provinces arrived at Dorpat in Russia." According to Ashbrook's original article (June 1963), Struve left Altona on July 7, 1808. The discrepancy is minor and to mention it seems like nit-picking, but this is how errors get propagated and care should have been taken to explain the change.

With that said, I have little else but praise for the book. It should serve as a model for future astronomical historians, and is a fitting tribute to its author. I'll put my copy right alongside such classics as Hutchinson's *Splendour of the Heavens*, King's *History of the Telescope*, and Warner's *The Sky Explored*. And you should find room for it on your bookshelf, too. *Don Trombino*.

Early Greek Astronomy to Aristotle
D.R. Dicks
272 pages, paperback, $9.95
Cornell University Press (1985)

First published in hardcover in 1970 and now reprinted in paperback, this book assesses the important contributions of astronomers such as Anaxagoras, Parmenides, and Eudoxus, many of whose works are known to us only in fragments

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176 pp., line drawings, photographs, $29.95

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223 pp., line drawings, photographs, $24.95

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Columbia University Press 136 South Broadway, Irvington, NY 10533

or through summaries by later writers. Dicks: "Modern commentators tend to underestimate the difficulties of [naked-eye] observation and to discuss the results as though the telescope, the micrometer screw, and the vernier scale were normal pieces of equipment in antiquity . . . .To differentiate between the planets themselves, and estimate their periods, must have taken centuries of observation."

Starwatch

Ben Mayer
144 pages, softcover, $7.95; hardcover, $15.95
Perigee Books (1984)

The author of a book has little or no control over the claims made for the book on its cover. That falls into the realm of the publisher, whose job is to make the book as saleable as possible. So it is with Ben Mayer's *Starwatch*, the cover of which proclaims it "the best, most comprehensive year-round viewing guide to the night sky." Anyone seeking such a book will not find it in *Starwatch*!

Now before you start thinking this is a negative review, I must engage in a little truth-in-advertising of my own. I'm a friend and admirer of Ben Mayer, as well as a fellow member of the Polaris Observatory Association. If I could not in good conscience write a favorable review of Ben's book, I simply would not write one at all. So now that you know the context in which this review is written, you're probably asking yourself: "All right, why should I buy this book?"

The reasons are several: Many potential amateur astronomers (and I hope you are one of them, or know somebody who is) need a book that will serve as a "Whitman's Sampler" of amateur astronomy. It's this goal that Ben Mayer set for himself in writing *Starwatch*. He states this in the introduction:

"This sky album shares some of the oldest and newest basic knowledge we have plucked from the heavens. It was designed by a lover of stars, an amateur astronomer (amator = lover). Rather than try to offer the whole celestial sphere all at once, it opens windows on the twelve zodiacal starfields and twelve other constellations, all readily visible over the course of a year from northern latitudes."

Starwatch contains just enough information about amateur astronomy to whet the appetite of anyone contemplating it as a hobby. In fact, in his obvious zeal to leave nothing out, the author has produced a somewhat cluttered book — but what glorious clutter! In what other book, for instance, could the neophyte astrophotographer see the field of a 35mm camera with 40mm, 50mm, and 135mm lenses superimposed on a photograph of the familiar starfield of the Big Dipper? Another example is the two-page section on meteors which manages to convey more useful information about their nature, how and when to observe them, and even how to photograph them than any other book I'm aware of.

Another component that makes *Starwatch* work is one of Ben Mayer's most ingenious inventions: the starframe. A starframe is little more than a metal coathanger, which has been unbent to form a rectangle and painted with typists' "White-Out" correction fluid. The beginner has only to follow the instructions in the book to correctly orient the frame with respect to the sky while holding the starframe at arm's length. Once that is done and "two of the brightest objects on the tracing are aligned with their counterparts in the sky, everything else falls into place."

Well, I tried out a starframe. Once I got used to changing my eye focus from frame to sky and back again, it was easy! The crucial test was in finding the constellation of Aquarius. Since this contains few interesting deep-sky objects, I'd never bothered to learn its rather imaginative configuration. Instead, I star hopped straight to those few deep-sky objects I wanted to observe. With the starframe, however, finding my astrological birth sign was easy! (Now, if only I could find a use for astrology . . . .)

However, the real reason to buy this book is that after reading it, you might find yourself infected with the same hopeless and thoroughly delightful enthusiasm for the stars which infects our astronomical schmaltz-king Ben Mayer. Nothing sums it up better than the fine print at the top of page 83:

"Glorious summer nights. The sky ablaze with myriad stars. The Milky Way waiting to be rediscovered, childhood memories to be recalled. What's out there? Where did we come from? Where are we going? Are we alone? How far is a galaxy? How long is eternity? The stars await."

I recommend *Starwatch* to all beginning "amators" of stars. *Richard Shaffer.*

The X-Ray Universe

Wallace Tucker and Riccardo Giacconi
201 pages, hardcover, $20
Harvard University Press (1985)

Tucker and Giacconi are both astronomers (Giacconi is the director of the new Space Telescope Science Institute); their book — one of the "Harvard Books on Astronomy" series — is "a selective and personal history of X-ray astronomy . . . [which] is no longer a new and exotic branch of astronomy." They have chosen this approach because the subject "is now part of the mainstream, and a comprehensive treatment of X-ray astronomy as a separate field is no longer feasible." The discussion, written with the interested layman in mind, focuses on the broad range of problems that X-ray astronomy can work on.

catch . . .

. . . a comet

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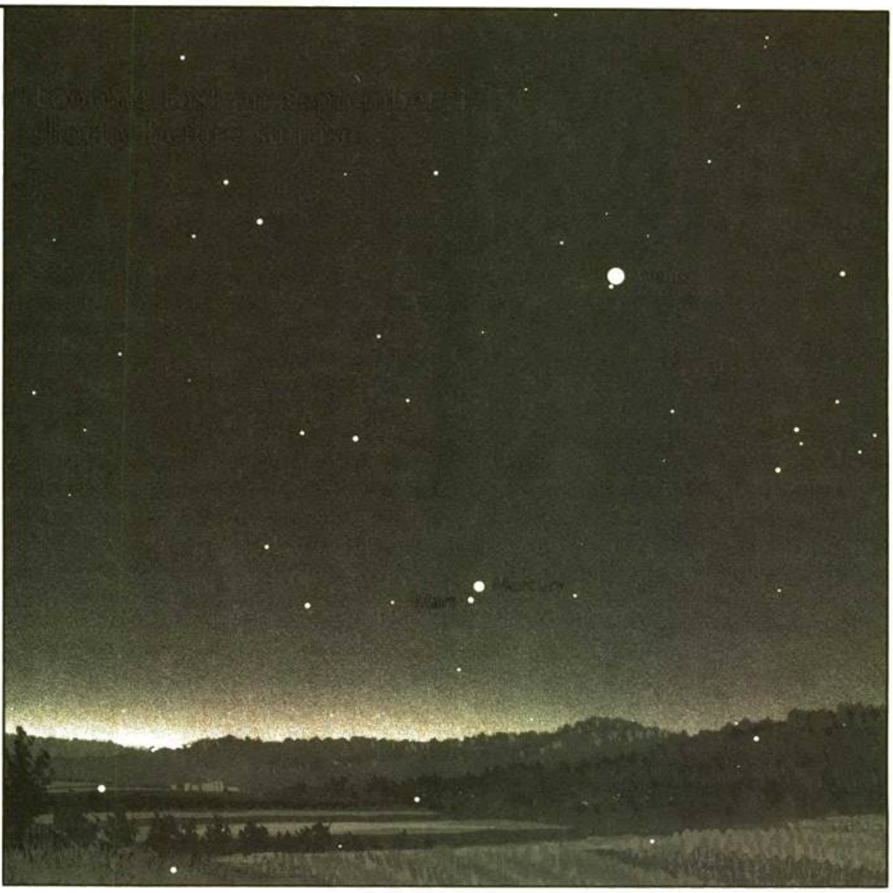
Mercury Meets Mars

by Fred Schaaf



The Wanderers

This September is a terrific time for observing the sky: all of the naked-eye planets are visible at some point during the month. As if this weren't enough, September also presents several remarkable conjunctions and the opportunity to observe — with telescopes — two comets, including one named Halley.

The most unusual conjunction of the month is visible only from parts of the eastern hemisphere. At about 21h UT on September 4th, **Mercury** will be less than 50 arc-seconds south of **Mars** in the morning sky — the closest conjunction of two planets visible this decade. Only twice before the year 2000 will there be any closer pairings of any planets.

The conjunction is not easy to view, since the planets lie only 16° from the Sun. Fortunately, Mercury is bright: magnitude −0.8. Unfortunately, the whole world cannot view this event — observers in the Americas will only see the pair the mornings before and after the conjunction, when they are farther apart.

On the American morning of the 6th, Mercury lies a full degree north of 1.4 magnitude Regulus — the star marking Leo the Lion's heart. At 1h UT on the 9th, Mars is 0.8° north of this star, but is considerably dimmer and no help in locating Regulus. (In binoculars, note the contrast of ruddy Mars and blue-white Regulus.)

Mercury spent the last month and a half completing a loop east of Regulus, but this month the planet moves on toward Spica in Virgo. Mercury reaches superior conjunction on the 22nd, six hours before autumn begins.

In the meantime, Mars is slowly gaining altitude as it nears a conjunction with **Venus**, again in the morning sky, in October. Do not confuse Venus with Mercury when searching for the Mercury-Mars pair around the 4th: although Mercury is near its brightest and Venus its faintest, the latter is still more than two magnitudes brighter!

For information on viewing the Moon, planets, and deep-sky objects with telescopes, see **The Backyard Astronomer**.

Several unusual conjunctions occur this month. On September 4th at about 7h UT, Venus lies only 52 arc-seconds south of Delta Cancri. You'll need binoculars, but observers without them can look for Delta near Venus on the mornings before and after.

On the 12th and 13th, as Mars pulls away from Regulus, the lovely crescent Moon lies several degrees north of Venus and later near the Mars-Regulus pair. As a finale, Venus will pass a mere 0.4° north of Regulus at about 17h UT on the 21st.

As September ends, magnitude −2.6 **Jupiter** is alone in the mid-evening sky and slowly pulling away from the slower-moving planets to the west. Opposition was last month so Jupiter is visible most of the night, setting only in the final hours of darkness. On the other hand, **Saturn**'s elongation decreases from over 70° to less than 40°, so it sets fairly early in the evening. It is rather dim now as it accelerates eastward in eastern Libra.

The Starry Sky

Cygnus the Swan is often called the Northern Cross; it now looks like a giant dagger overhead. The grip of the handle is marked by Deneb, the Swan's brightest star; the juncture of the handle and blade is second-magnitude Sadr (Gamma Cygni); the point of the blade is third-magnitude Albireo (Beta Cygni). The dagger points southwest down the Milky Way and seems to have cut a gaping tear in the soft luminous glow — this is the Great Rift, formed not by an absence of stars but by obscuring clouds of dust and gas.

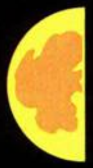
Cygnus will remain a well-placed constellation throughout autumn. South and southeast of it, however, are constellations which make a shorter arc across the southern sky. Although these patterns are faint — to see them, try driving out into the country toward the middle of the month — the effort of learning them is worthwhile because this region holds some of the most subtle of all constellations.

The region is often called the Water or the Great Celestial Sea, and it's easy to see why. Five vast constellations — plus bordering ones like **Delphinus** the Dolphin, **Grus** the Crane, and **Eridanus** the River — are all marine or water-related.

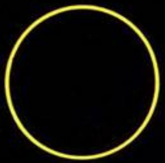
Capricornus follows summer's Sagittarius in the zodiac; like Sagittarius, it is supposed to represent a composite

This photo of Orion resulted from a 2-minute guided exposure with a 50mm f/1.4 lens tracking on the stars, then a 5-minute gap with the camera lens covered, and finally a 15-minute unguided exposure. Photo by Charles Strickland.

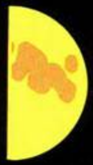
September's Night Sky



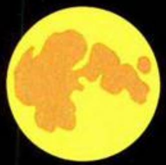
Last Quarter
September 7
8:16 p.m. EDT



New Moon
September 14
3:19 a.m. EDT

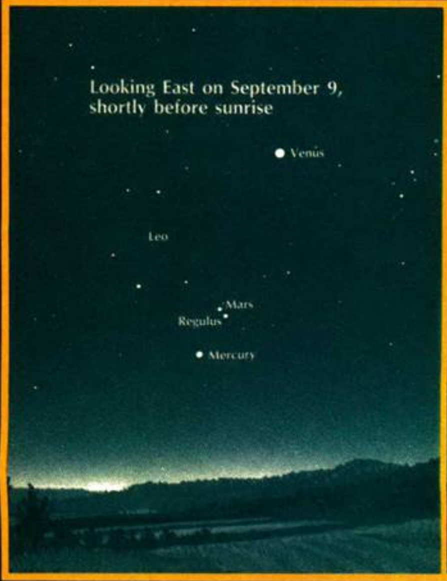


First Quarter
September 21
7:04 a.m. EDT

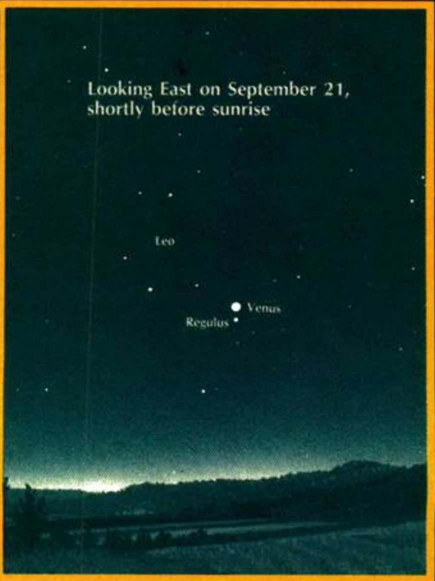


Full Moon
September 28
8:08 a.m. EDT

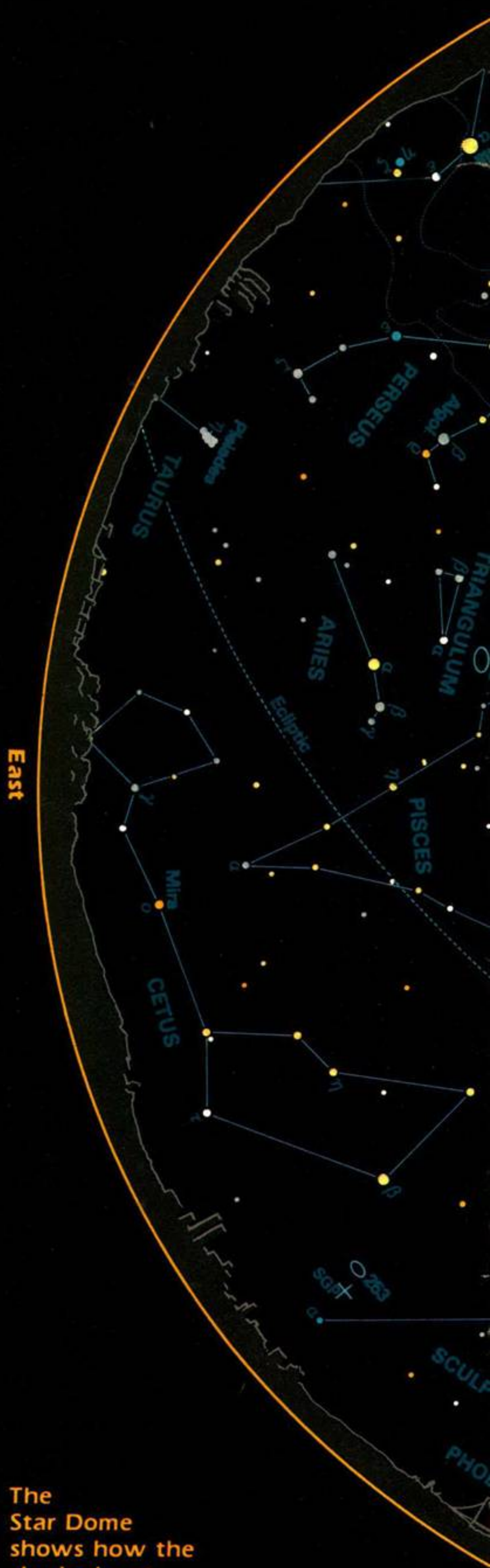
4th	The Moon is farthest from Earth at 6:02 p.m. EDT: 251,526 miles. An hour earlier, magnitude −0.8 Mercury passes 0.01° south of fainter Mars; they lie 16° from the Sun in the morning sky.
7th	Last Quarter Moon occurs at 8:16 a.m. EDT. Epsilon Perseid meteors peak — you may spot up to 10 per hour.
9th	Magnitude 2.0 Mars lies 0.8° north of Regulus, about 14° from the Sun in the morning sky.
14th	New Moon is at 3:19 p.m. EDT.
15th	Around 1 a.m., you can see the stars of summer setting in the west while Orion and his winter retinue rise in the east.
16th	The Moon is closest to Earth at 2:44 p.m. EDT: 225,121 miles.
18th	The Moon passes 3° south of Saturn in Libra.
20th	In Ophiuchus, the Moon travels 3° south of Uranus.
21st	First Quarter Moon occurs at 7:04 a.m. EDT. On the same day, magnitude −3.4 Venus passes 0.4° north of Regulus; both are some 29° away from the Sun.
22nd	The autumnal equinox arrives at 10:08 p.m. EDT as the Sun crosses the celestial equator. At 4:00 p.m. EDT, Mercury is at superior conjunction with the Sun.
24th	The Moon passes 4° south of Jupiter.
28th	Full Moon occurs at 8:08 p.m. EDT.



Looking East on September 9, shortly before sunrise

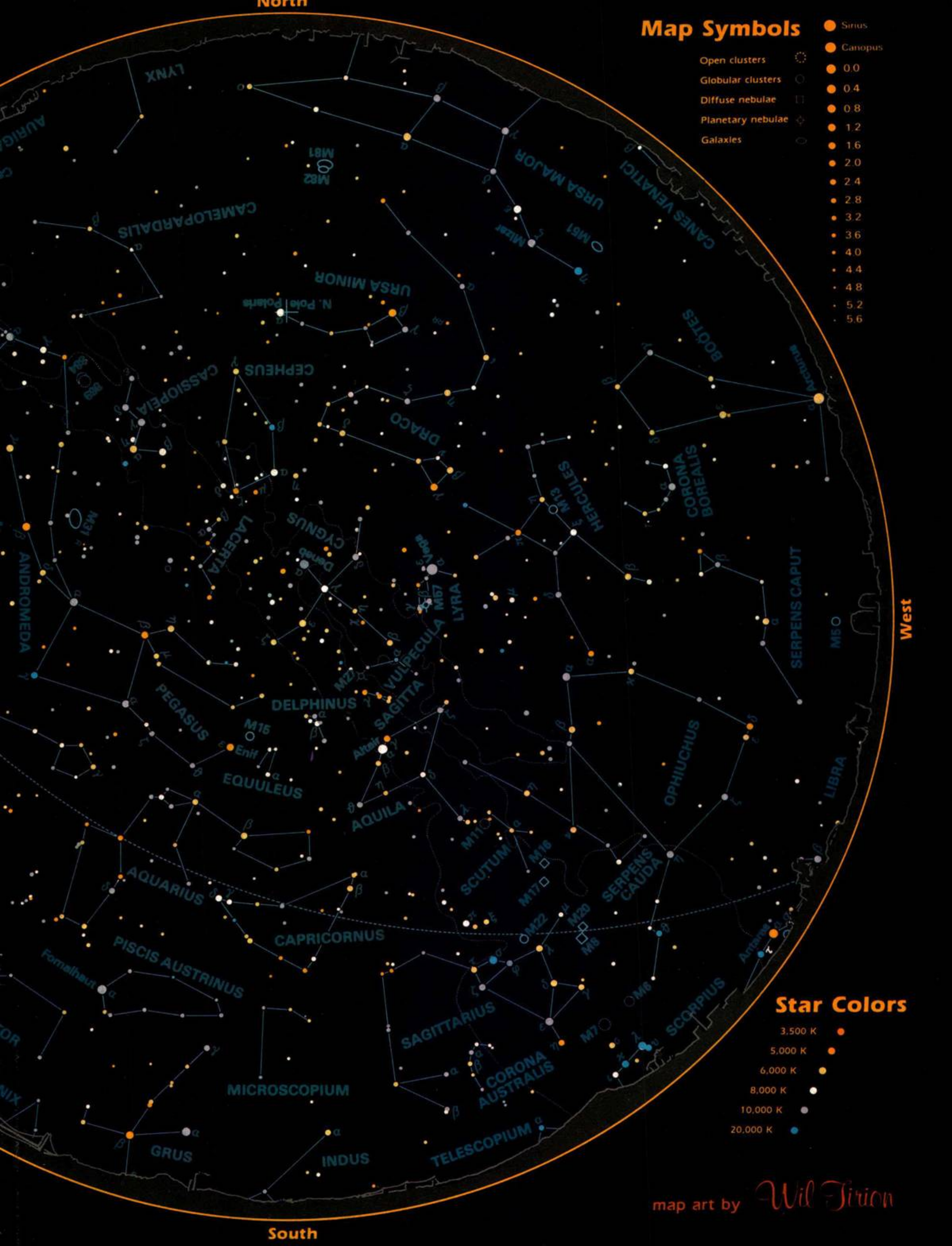


Looking East on September 21, shortly before sunrise



The
Star Dome
shows how the
sky looks at:

11:30 p.m. on September 1st
10:30 p.m. on September 15th
9:30 p.m. on September 30th


North
Map Symbols
Open clusters
Globular clusters
Diffuse nebulae
Planetary nebulae
Galaxies
Sirius
Canopus
0.0
0.4
0.8
1.2
1.6
2.0
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LYNX
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CAMELOPARDALIS
URSA MAJOR
Mizar
M51
CANES VENATICI
URSA MINOR
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DRACO
BOÖTES
Arcturus
CORONA BOREALIS
HERCULES
M13
M31
LACERTA
CYGNUS
Deneb
Vega
M57
LYRA
ANDROMEDA
SERPENS CAPUT
M5
West
VULPECULA
M27
SAGITTA
DELPHINUS
PEGASUS
M15
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M11
SCUTUM
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M22
M20
M8
Antares
PISCIS AUSTRINUS
Fomalhaut
M6
SCORPIUS
SAGITTARIUS
M7
CORONA AUSTRALIS
MICROSCOPIUM
GRUS
INDUS
TELESCOPIUM
Star Colors
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5,000 K
6,000 K
8,000 K
10,000 K
20,000 K
South

map art by Wil Tirion

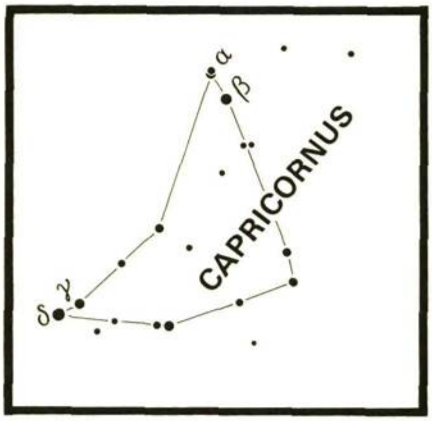
Above: A misty aurora looms over Washington's Lake Roosevelt in this 50mm f/1.8 camera-on-tripod exposure. Photo by Don Carney. Below: A 400mm f/7 lens and 10-minute exposure on 64 ISO film captured the Moon rising over Milwaukee. Photo by John Asztalos.

creature. In this case, the creature is part goat in front and part fish in back. This odd beast, probably derived from Mesopotamian mythology dating back 5,000 or more years, represents a Sea-Goat — although the name is Latin for "horned goat."

The most important stars of Capricornus lie at the eastern and western ends. The western (right-hand) end holds two doubles, Alpha Capricorni (Giedi — just separable with the naked eye) and Beta Capricorni (Dabih — requires binoculars). The tail is marked by Delta Capricorni, also called Deneb Algiedi. This year the Sea-Goat is overwhelmed by a visit from Jupiter.

If you gaze northeast or southeast from Capricornus and Jupiter, you will see two bright stars which stand out amidst the others. The northern of the two is second-magnitude Enif, Epsilon Pegasi, the "nose" of **Pegasus** the Winged Horse. Toward the southeast is Fomalhaut, "the mouth of the fish" in **Piscis Austrinus** the Southern Fish. It is the only first-magnitude luminary among the traditional fall constellations.

Between Enif and Fomalhaut is a sprawling constellation which requires dark skies to see well. This is **Aquarius** the Water Bearer. A line from Fomalhaut to Enif will almost pass through a moderately bright star not too far southeast of Enif: this is Alpha Aquarii, also known as Sadalmelik. Sadalmelik sits almost on the celestial equator (but above the ecliptic), and so does the asterism in Aquarius which follows it — the Urn or Water Jar from which Aquarius pours water. Aquarius, by the way, is the constellation Halley's Comet will travel through from late December until late February, and there it will also reach perihelion.



Pisces the Fish and **Cetus** the Whale are still rather low in the east at mid-evening, but Piscis Austrinus lies due south of Aquarius and can be conveniently viewed. This Southern Fish contains only a faint loop of stars, except for glorious Fomalhaut.

For most readers, Fomalhaut rises about the same time in the southeast as does Capella (in **Auriga** the Charioteer) in the northeast. But Capella will not culminate in mid-evening until winter is practically upon us, whereas Fomalhaut reaches its highest elevation next month. Fomalhaut's pronunciation is much debated: many people say the final syllable to sound like "low," as if the name were French. Actually it is Arabic and is pronounced "FOAM-AL-HAWT."

Skylore

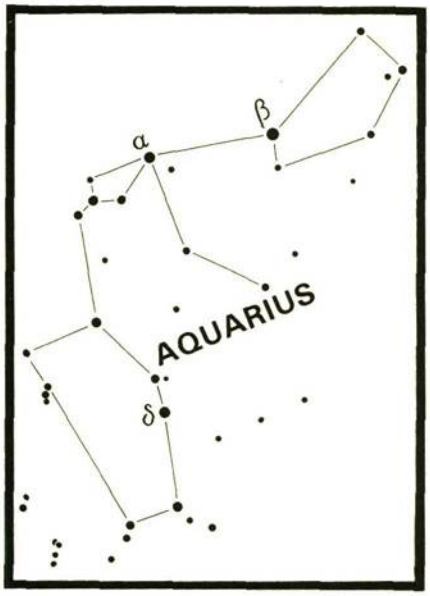
The summer Milky Way arches across our heavens in the early evening. Even though we know it is the combined glow from billions of distant stars in the disk of our home Galaxy, its soft mysterious beauty still lends imaginative credence to the many legends which purport to otherwise explain it. Curiously, a few cultures saw the Milky Way not as a river or a chain or a backbone, but as a *road*.

The idea of the Milky Way as a path is more common than one might think. But what kind of path? Perhaps a path for the gods. A Greek account tells that Phaeton lost control of the chariot of the Sun and burned many stars, leaving a pale trail of ashes in the heavens. The Welsh regarded the Milky Way as the path which their god Gwydion took in search of his missing, wounded son. The Celtic name for the Milky Way is Arianrhod, the Silver Circle — a name also given to Corona Borealis. In Anglo-Saxon myths, the Milky Way was the Way of Irmin (or Iringe), a god who drove a bronze chariot which some have identified as the Little Dipper, left tied to the North Pole when not in use.

Some people saw animals — usually sacred — on this path. The Siamese called the Milky Way the Road of the White Elephant. The Blackfeet Indians called it Makoye-osokay, the Wolf Way. One of the Incas' ideas about the Milky Way was that it was an especially high trail on which llamas roamed. The Patagonians believe this trail is traveled by their dead friends hunting for giant rhea birds.

One of the most popular beliefs about this "sky road" is that its users are spirits of the dead. Many American Indian tribes have a version of this, some claiming that the first part of the path was guarded by a dog — Sirius — but good spirits could freely traverse the whole length to reach paradise at its end near the star Antares. The Algonquin Indians called the Milky Way the Path of Souls which led to the villages of the Sun. The Norse knew the Milky Way as the Path of Ghosts over which fallen heroes marched to Valhalla. Medieval Christian legend pictured angels or saints on this road to heaven, and it was variously called Saint Hilda's Street, Road of Saint Jacques of Compostella, and Walsyngham Way — the path of the Virgin Mary in the sky.

Sometimes the road was a trail of something left behind or dropped by a traveler. In a number of cultures, the Milky Way represents straw. One of the most delightful Milky Way legends comes from the Cherokee Indians, who tell of a dog following and eating the cornmeal which his mistress spilled as she was carried off by a kidnapper. Author R.H. Allen recounts a legend in which Isis fled Typhon, leaving a pathway of dropped corn ears on her way.



The most famous substance considered to have spattered in a trail, thus forming the luminous band, is milk. Milky Way is derived from the Latin *via lactea*. According to legend, the Roman queen of the gods, Juno (Greek Hera), nursed the baby Hercules not realizing his identity. The powerful babe bit too hard and Juno cast him from her, spattering milk across the heavens to form the Milky Way. Juno hated Hercules throughout his life because he was the son of her husband Jupiter — Zeus — and one of his countless mistresses.

The Milky Way was sometimes considered a bridge. In one Finnish tale, the bridge was built by two separated lovers — Zulamith and Salami — who completed it after a thousand years and immediately flew into each other's arms where they became Sirius, the brightest of stars. The Finns also call the glowing band Linnunrata, Bird's Way, from the belief that souls grew wings and flew on this path to a land of gladness. Another version is that all bird songs turn into a cloud of snow-white dovelets which evermore are seen as the Milky Way.

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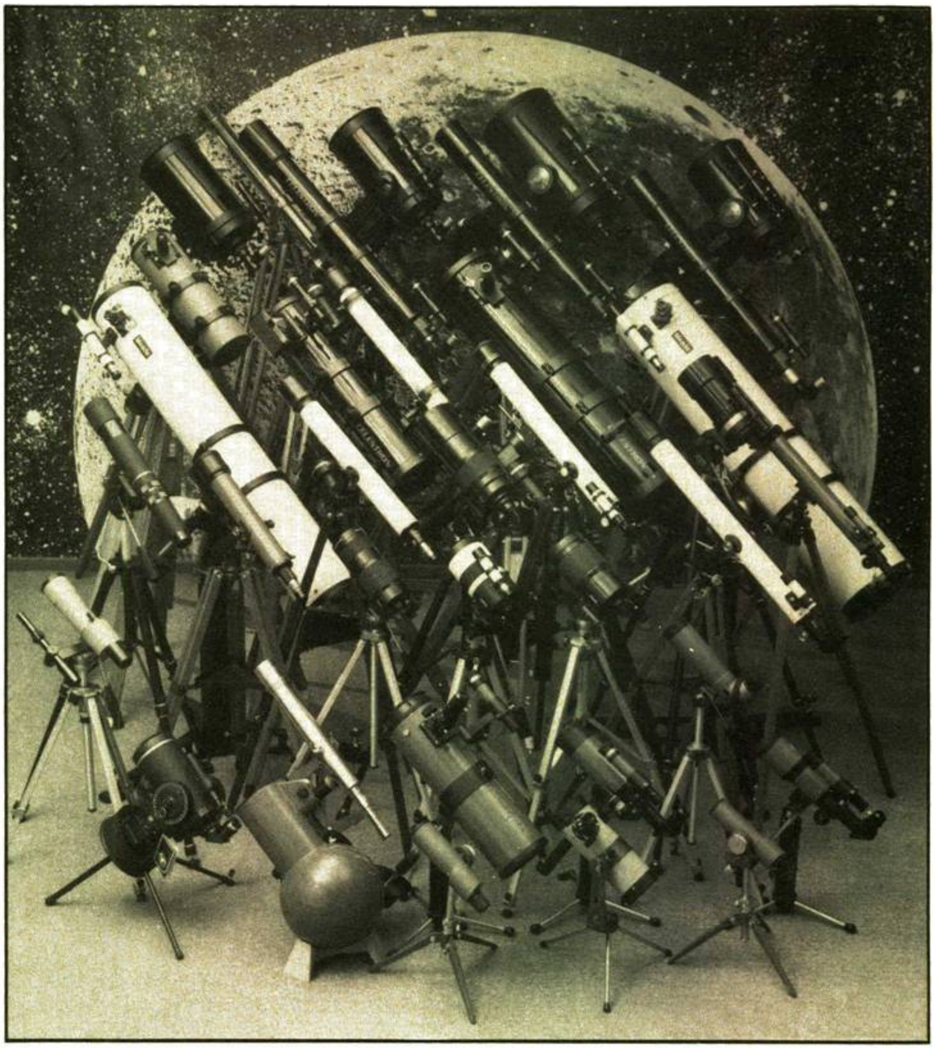

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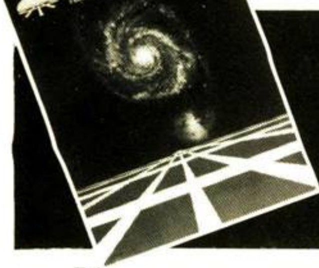

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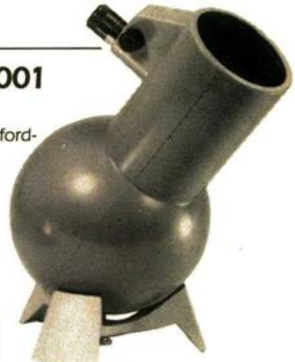

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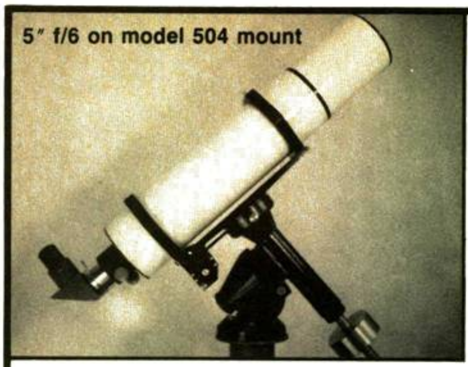

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A Portable Astrophotography Platform for Travelers

by
Robert Reeves

The astrophotographic event we've all been waiting for is drawing near — Halley's Comet will soon come flying past in its full glory. For many of us, this means a long-planned trip to the southern hemisphere for a better view. But traveling to see and photograph Halley presents some problems because typical celestial photo rigs weigh something like twice your airline baggage allowance!

Several years ago, I found myself 100 miles away from my heavily light-polluted home town looking up at Comet IRAS-Araki-Alcock. The comet was a pretty little cotton ball hung in a jet-black sky. But where was my astrophoto gear? Back home in the garage, of course. That night, I decided to create a small, easily transportable device that would let me do astrophotography anywhere with an ordinary camera. The result was my portable equatorial guiding platform.

While similar in basic concept to the Haig (or "Scotch") mount detailed in the September 1984 issue of ASTRONOMY, my device allows some additional adjustments beyond right ascension. The drive platform gives precise crosshair guiding in right ascension, declination control, latitude adjustment, and accurate polar alignment — in short, all the essentials for fully-guided astrophotos. Moreover, the platform collapses into a self-contained unit only 5x9x14 inches in size. All the mountings, guide and alignment scopes, and adjusting hardware conveniently stash within, making it easy to carry on trips.

Since the guider is manually powered, you are freed from dependence on electricity. And, of course, there's no drive motor to reverse for the southern sky: You simply turn the right ascension control in the other direction when using it south of the equator. Although you can use the guider with a big photo tripod, you don't need one; the unit works very well clamped to a flat sturdy table. (Even the C-clamps stow inside!)

There are as many different ways to build a guiding platform as there are astronomers capable of basic woodworking. Therefore I'm not going to give exact plans, but rather show you the basic principles involved and let you custom build your own model. Believe me, it's not hard.

The overall dimensions of the platform are dictated by the size of the components you'll store inside. In mine, the pole finderscope is a discarded stock Celestron 6x30 "soda straw" finder. The guidescope is an 8x50 Celestron right-angle finder I picked up cheap at the Texas Star Party a year ago. Both finders need mounting brackets; get the one-piece kind. The camera and guidescope ball-swivels are from Spiratone, Inc. (a New York photo supply house) and cost about $15 each.

The platform is a plywood box with a single flap on one side and a double flap on the other (see photos). The box is basically ⅜" ply, but there are a few exceptions as noted. The single flap (made from ¾" ply for strength) goes on the bottom side of the box and is hinged along its southern edge to tip the platform upward, aiming its short edge toward Polaris. This flap provides the latitude adjustment. (For convenience, I built the Polaris finderscope permanently into the box, cutting two viewing ports in the north and south sides. These are covered with little sliding doors when the unit is closed for transport.)

On the top side of the platform, the lower of the double flaps is hinged to the box along its western edge to act as a polar axis, and the top flap is hinged along its northern edge to provide declination control (again, see the photos). Opening the entire box lid gives right ascension motion, and opening the top flap alone provides declination. If the western hinge is properly aligned with Polaris, the double-hinged box top provides control in both celestial axes.

As I mentioned, there are no drive motors — you power the whole thing manually using three jack-screws made of ¼-20 threaded rod. One jack-screw tips the box to align on the pole. A second jack-screw drives the right ascension flap and the third raises or lowers the second top flap for declination control. The right ascension jack-screw also serves to bolt all three flaps together when you close the box for storage.

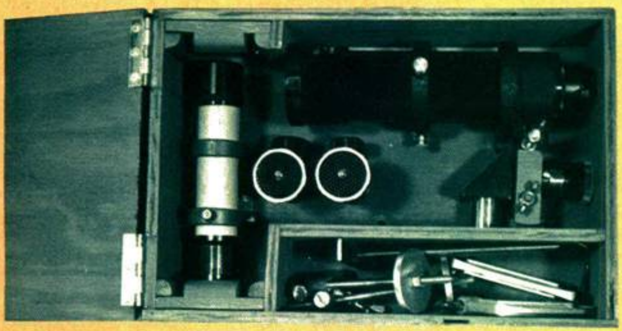
The right ascension screw is the longest (about 7") since it must pass through the box. The declination and latitude screws are each about 5" long, but the exact lengths depend on the size of your platform, what latitudes you intend to use it at, and how much declination motion you want. I sharpened one end of each threaded rod on a grinder so they wouldn't creep in use: the sharp ends fit into indents made by gently hammering the points into the wood.

Each of the screws has a hand control knob; within reason, the larger you make them the easier they'll be to use in the dark. My latitude and declination control wheels are 2"-diameter aluminum discs cut out with a hole saw, but thin plywood would work perfectly well also. For the right ascension control, I made a large T-bar. This gives me a bit more leverage on the jack-screw (you're turning it constantly, remember) and minimizes touch-induced vibrations. The disks and T-bar were each drilled to fit over the threaded rod, and are clamped tightly between two ¼-20 nuts.

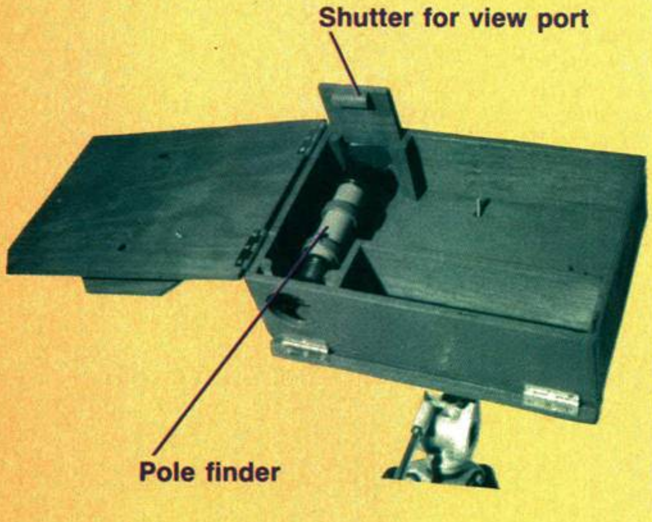
You must provide some means to let the jack-screws tip as the flaps open or close. Without this, the ends of the jack-screws eventually will scrape, bind, or pinch against the underside of the flaps as they slowly pull to one side. My solution was to drill and tap (to ¼-20) half-inch shafts, using them as combination bearings and rocking pivot points for the jack-screws.

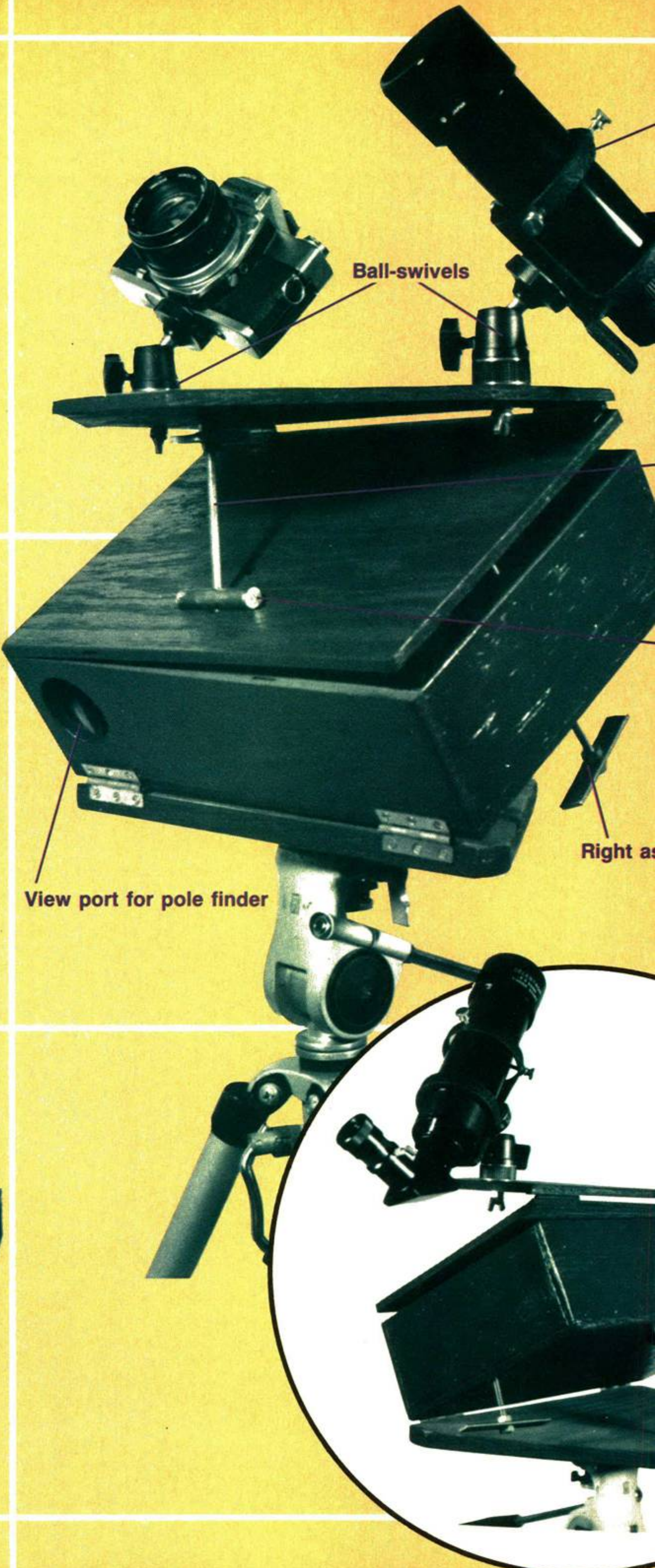
Two of the half-inch shafts nestle into shallow grooves cut in the wood of the guider; at the bottom of each groove is an oversized hole for the jack-screw rod to pass through. The right ascension shaft is simply wedged into the angle between the

All closed up and ready to go.



Inside nestle two ball-swivels, the guidescope and pole finder, and the jack-screw hardware.

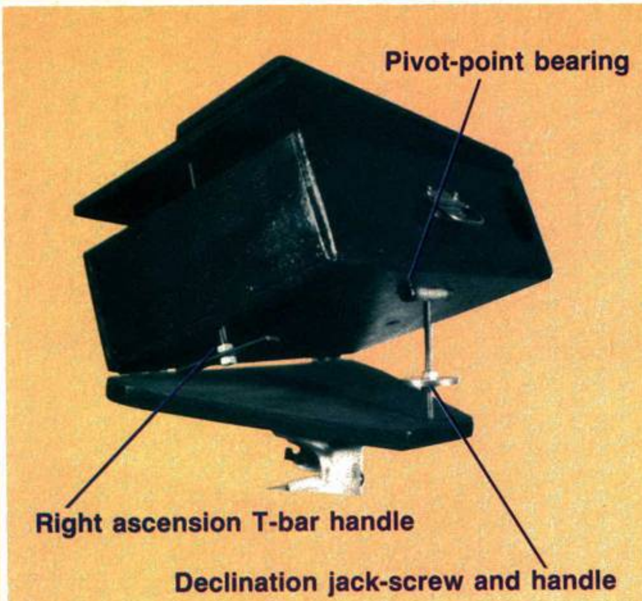

Shutter for view port
Pole finder

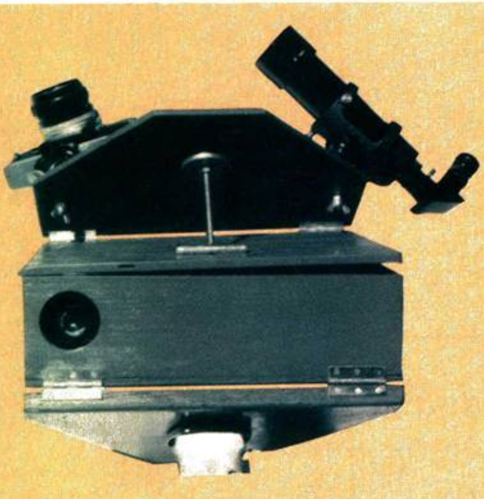

Ball-swivels
View port for pole finder
Right as

Guidescope
eclination jack-screw

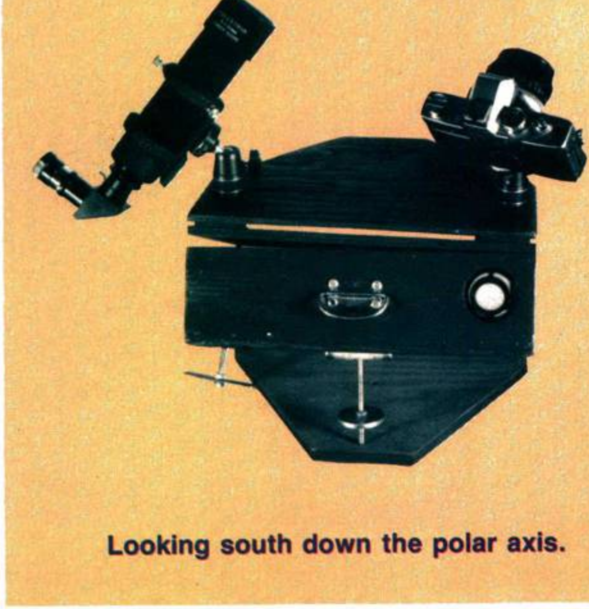
-Pivot-point bearing

ension T-bar handle


Pivot-point bearing
Right ascension T-bar handle
Declination jack-screw and handle



Looking north up the polar axis.



Looking south down the polar axis.

All photos by the author.

box bottom and side, where the down-pressing weight of the two upper flaps plus camera and guidescope holds it in place. (Be sure to drill the hole for the right ascension jack-screw as close to the box edge as you can.) The shafts I used were half-inch steel bolts with the heads and threads cut off, but I wouldn't do that again: the steel was very tough to drill. Instead, use half-inch aluminum bar stock.

The jack-screws have fairly limited travel. Half an hour is about the limit for right ascension, but this doesn't matter very much since half an hour is plenty with most fast films at wide-open f/ratios. The declination motion is only for "touch ups" in the guiding and for keeping the top flap as level as possible.

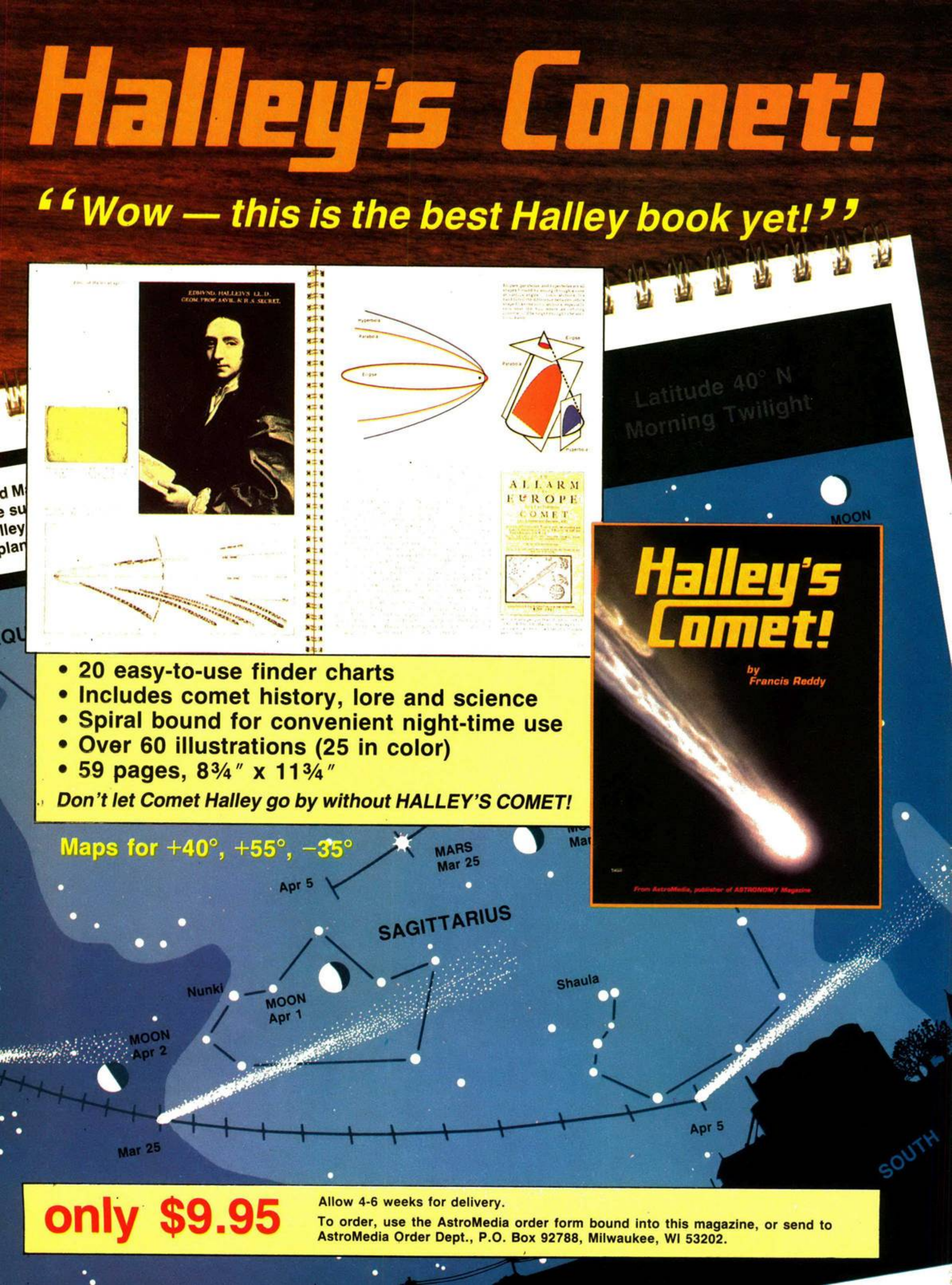
The ball-swivels for camera and guidescope are bolted to the top flap with short countersunk ¼-20 screws; place them as shown in the photos for good balance. You'll have to drill and tap the guidescope's mounting bracket — again, use ¼-20 to match the thread on the ball-swivel.

In use, I've found the lack of an illuminated reticle eyepiece is no problem at all. Since the guidescope can be aimed anywhere in the sky, you simply select a bright star and defocus the image to produce a blob. It's then quite easy to keep the silhouetted crosshairs centered on the blob. With long-focus lenses (100mm or more, say), you'll have to pay close attention to the guiding — but even so, I've found it's no great effort to make half-hour exposures. With wide-angle lenses it's a lot easier — you can correct the guiding at 5 to 10 second intervals and the stars will still photograph perfectly crisp.

One warning: while I have used the guider on my heavy-duty photo tripod, the average tripod used with a 35mm camera probably won't be strong enough. In that case, I suggest you look for a sturdy picnic table or the like and C-clamp the platform to it. The tripod attachment is a small piece of ⅜" thick steel plate, tapped for ¼-20 in the center and with countersunk screw holes in the four corners. It fits into a routered recess in the bottom flap and is held in place by wood screws.

Even if you're not planning to travel south for Halley's Comet, a hand operated guiding platform such as this should give you hours of astronomical tinkering and fun. Best of all, when your friends brag about the great piggyback exposure they took atop their $1,500+ 8-inch Schmidt-Cass, you can haul out your equally good shot taken with the guider you made for less than the price of a high-grade eyepiece!

Robert Reeves has been an active astrophotographer for the past 25 years; his most recent ASTRONOMY article was "Making an Astrophotographic Mosaic" in the March 1985 issue.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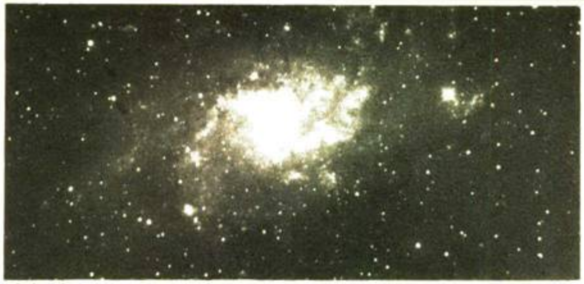
LUMICON FOR HIGH PERFORMANCE

ASTROPHOTO OF THE MONTH



Spiral Galaxy M-33 in Triangulum. This low surface brightness galaxy is seen best visually with a LUMICON DEEP-SKY Filter. Photo by Dr. Jack Marling using a LUMICON Newtonian EASY-GUIDER and 2415 film sensitized in a LUMICON Model 300 HYPER-KIT; 40 min. exposure, 10"f/5 telescope.

48mm COLORED FILTERS

Upgrade to 48mm filters! All are multi-coated

UV, Green, Yellow, Orange, Red	**$14 each**
48mm H-Alpha Pass (640nm cut-off)	**$30**
48mm Minus Violet (420nm cut-off)	**$20**
48mm High perform blue, 90% trans	**$30**
UV-370 U-Band, 320-420nm bandpass	**$15**
48mm Polarizer (2 make variable density)	**$25**
Set 9 ea. 48mm filters ($175 list)	**$148**
2"/1¼ adapter threader for 48mm filters	**$20**

H-ALPHA PASS FILTER

Yields spectacular contrast gains in B&W photography with telephoto lenses. Yields pinpoint star images. Superb with hypered 2415. For color, use the Minus Violet (MV) Filter.

Specify Lens Size	H-Alpha	(MV)
46, 48, 49mm	$35.00	$29.00
52, 55, 58, 62mm	$45.00	$35.00
67, 72, 77mm	$52.00	$45.00
82mm	$55.00	

Hypered 2415 film, 36 exp . . . **$9.95** . . . **3/$27**

TELE VUE™ EYEPIECES USE THE BEST!!

ALL IN STOCK
DEDUCT $6 each, Plossls

7.4, 10.4, 13, 17, 21, 26mm Plossl, 50°	**$80**
1.8x or 2.5x Tele Vue Barlow Lens	**$80**
32mm Plossl, widest true field in 1¼"	**$95**
55mm 2" Plossl, widest possible field	**$175**
15mm Wide-Field, 1¼" eyepiece, 65°	**$110**
19mm Wide-Field, 1¼" eyepiece, 85°	**$125**
24mm Wide-Field, "superb", 65°	**$140**
32mm Wide-Field, 2" eyepiece, 65°	**$210**
40mm Wide-Field, "awesome", 65°	**$265**
4.8mm Nagler, 82° field	**$140**
7mm Nagler, 1¼" eyepiece, 82° field	**$175**
9mm Nagler, 82° field, "the best"	**$210**
11mm Nagler, 82° field, 1¼" or 2"	**$225**
13mm Nagler, 82° field, 1¼" or 2"	**$235**

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NEW! ENHANCED SILVER DIAGONAL MIRRORS BOOST TELESCOPE PERFORMANCE

LUMICON 1.3" & 3.1" enhanced silver diagonal mirrors & 2" star diagonal.
The new LUMICON diagonal mirrors have a special enhanced silver coating with a protective overcoating for long life. Visible reflectivity is 98-99% compared to 86-89% for standard aluminum coated mirrors. The extra 10-12% transmission is like adding an inch of aperture! The substrate is fine annealed Pyrex flat to 1/8 wave.

1.32" . **$29.95** 1.52" . **$34.50** 1.83" . **$39.50**
2.14" . **$47.50** 2.60" . **$59.50** 3.10" . **$79.50**
4.25 . **$129.50**

ENHANCED SILVER STAR DIAGONAL

90° star diagonals with above enhanced silver mirrors in a CNC machined black anodized aluminum body. Performance far exceeds prism diagonals.

1¼" (1.32" mirror)	**$79.50**
2" (1.83" mirror)(see photo above)	**$129.50**

LUMICON FILTERS STOP LIGHT POLLUTION

DEEP-SKY FILTER™

The **LUMICON DEEP-SKY FILTER** improves your view of **all** deep-sky objects including galaxies and comets. It removes natural and man-made light pollution and yields 3-6x contrast gain for nebulae and 1-3x contrast gain for clusters and galaxies. It is ideal for **both** visual use and B&W or color photography. This gentle filter yields the most natural view of any LPR filter available today. 90nm visible bandpass. 442-532nm. H-Alpha 656nm transmission = 80-95%.

"I CAN SEE THE VEIL NEBULA!"
Rich Zepernick saw the Veil Nebula for the very first time with a LUMICON UHC Filter. He stated, *"It was actually there! and not just around 52 Cygni, but the whole loop! Words cannot possibly express my feelings. I don't know how I managed without these filters."*
Zepernick, Cresskill, NJ

For optimum astronomy, use either the **LUMICON DEEP-SKY Filter** or the **LUMICON UHC Filter**

LUMICON UHC FILTER™ ULTRA HIGH CONTRAST

The **LUMICON UHC FILTER** is specially designed for visual astronomy in areas of severe light pollution or for viewing very faint nebulae at any location. **UHC** stands for **U**ltra **H**igh **C**ontrast and this filter is guaranteed to yield a higher visual contrast on planetary and emission nebulae than any other filter at any price. 24nm visible bandpass, 482-506nm.

	Standard	Premium*
1¼" **LUMICON DEEP-SKY Filter** threads into most 1¼" eyepiece		**$78.50**
48mm LUMICON DEEP-SKY Filter (1.75" aperture), threads into most 2" eyepieces. Also fits LUMICON EASY-GUIDERS		**$119.50**
2" LUMICON DEEP-SKY Filter (1.5" aperture), threads into most 2" eyepieces. Also has male & female camera T-threads for prime focus photography	**$99.50**	**$119.50**
72mm LUMICON Giant DEEP-SKY Filter (62, 67, 77mm adapter, $8)		**$299.50**
1¼" **LUMICON UHC Filter** threads into most 1¼" eyepieces	**$79.50**	**$99.50**
48mm LUMICON UHC Filter (1.75" aperture) fits most 2" eyepieces	**$149.50**	**$189.50**
Set of Both 1¼" **DEEP-SKY** and **UHC Filters** (Save 11%)	**$125.00**	**$159.50**
Set of Both 48mm **DEEP-SKY** and **UHC Filters** (Save 13%)	**$219.50**	**$269.50**
1¼" H-BETA Line Filter 9mm bandpass at 486nm). For the California Nebula, Horsehead Nebula, and other extremely faint nebulae)		**$89.50**
48mm "Horsehead Nebula" H-BETA Line Filter		**$169.50**
Oxygen-III Filter for very faint planetary and diffuse nebulae, 11nm bandpass at 500nm. 2X higher contrast than UHC filter	**1¼" $99.50,**	**48mm $189.50**
Telephoto lens adapter for 2" or 48mm filter. Select 46, 49, 52, 55, 58mm		**$6.95**
Universal adapter for 1¼" filters. Adapts the 1¼" filters to any 1¼" eyepiece		**$16.00**
Universal adapter for 48mm or 2" filters. Allows use of any 1¼" eyepiece		**$20.00**

**Premium filters are selected best of the lot and typically have 5-10% higher transmission. Not always available. Include individually measured transmission data.*

DEEP-SKY ASTROPHOTOGRAPHY

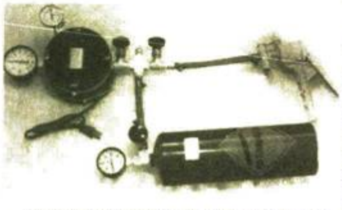
FILM HYPERSENSITIZATION KITS†

LUMICON HYPER-KITS™ yield 3-15X film speed gain in long exposures. They are safe & simple to use. Easy HYPER-KIT includes a chamber with all controls and fittings, thermometer, a refillable cylinder of non-flammable forming gas & hand-operated vacuum pump.

†Patent Pending

MODEL 100 HYPER-KIT for 35mm film, rolled-up. *Takes longer,* but it easy to use. Not recommended for 2415 . . . . **$225.00**

MODEL 300 HYPER-KIT sensitizes any 35mm film in hours. Best for 2415. Achieves highest possible film speeds **$295.00**



MODEL 600 HYPER-KIT [See Photo] Like the Model 300, but also sensitizes 120/220 larger format film and small glass plates **$325.00**

MODEL 1200 HYPER-KIT is for 4X5" plates and film up to 5X7". Has 2 gas cylinders and includes temperature controller **$525.00**

Temperature controller for any HYPER-KIT **$59.50**

Electric Vacuum Pump **$280.00**

GUIDE OFF-AXIS FOR LOVELY ASTROPHOTOS

All **LUMICON EASY-GUIDER™** off-axis guiders† have both radial and 360° rotational adjustments for 5X eaiser guide-star selection, use 48mm filters, 360° camera rotation, large prisms fo bright guide-starts. *Specify Camera and Telescope type.*
U.S. Patent # 4,448,500

NEWTONIAN EASY-GUIDER™

Full aperature. Installs in secs. Specify 2" or 1¼".

NEWTONIAN EASY-GUIDER	**$149.50**
3X Relay Diagonal [See Photo]	**$69.50**
Illuminated reticle eyepiece system	**$69.50**

CASSEGRAIN EASY-GUIDER™

For C-8, Meade 2080, Dynamax-8. Includes 50mm achromatic lens for f/5.8 operation-3X shorter exposures! **Superb rich field viewing, too!**
CASSEGRAIN EASY-GUIDER **$199.50**

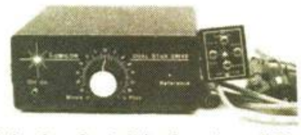
GIANT EASY-GUIDER™

For Celestron-11, C-14, and the 10" Meade 2120. Includes 80mm clear aperture achromatic lens for edge-to-edge illumination & pin-point star images. F-ratio adjustable f/4-f/11. **Also yields unmatched Rich-Field viewing.**

GIANT EASY-GUIDER	**$359.50**
48mm DEEP-SKY Filter ordered with any EASY-GUIDER [SAVE $20]	**add $79.95**
Premium ($119.50 list)	**$99.95**

WHAT DO YOU NEED?

1. **Illuminated reticle eyepiece** **$69.50**
Lumicon 12mm eyepiece system has adjustible L.E.D. illumiation, dual crosslines, battery pack.
2. Cable release for long exposures . **$9.95**



3. **Lumicon Quartz Drive Corrector** . . . **$194**
Dual-axis drive corrector is essential for astrophotography and/or field use of your telescope. 40Hz/80Hz variable output controls telescope drive. 60 Hz Quartz reference, ± 12VDC Declination control output. Both 110VAC and 12VDC input for home or field use. Declination reverse switch for Newtonians.
Declination moter (telescope) **$95**

HYPERSENSITIZED FILM

LUMICON Hypersensitized film is essential for good deep-sky astrophotography.

Film Type (35mm unless marked)	Exposures	Price
2415, Ultra-fine B&W, red sens	36	**$9.95**
VR200, fine grain color negs	12	**$9.95**
Fujichrome 400, "Excellent"	20	**$12.95**
SR1600, fastest of all, color negs	24	**$12.95**
5072, color slides from negs	36	**$6.95**
D-19 B&W Developer	1 gal.	**$6.95**

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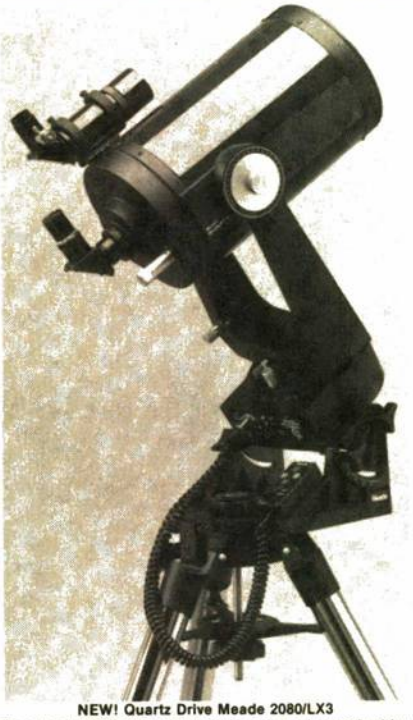
Meade® TELESCOPES AT LUMICON

2080/LX3 . . . .$1750

2080/LX3 System w/wedge & tripod ($2800 List)	$1750
2080/LX2 System w/wedge & tripod ($2450 List)	$1495
Multi-coated silvered optics	add $149
#36 dual-axis drive corrector control box	$99
#38 declination motor & clutch	add $99
Dew shield and accessory tray	add $89



NEW! Quartz Drive Meade 2080/LX3

The Meade 2080/LX3 with built-in quartz electronic drive system is positively the highest performance 8" Schmidt-Cassegrain telescope system available today.

- ★ Certified diffraction-limited optical system
- ★ Built-in quartz microelectronic sidereal drive system
- ★ 8x50mm right-angle illuminated Polar viewfinder
- ★ Multi-coated prism star diagonal (99% transmission)
- ★ 25 ft. cord for field operation from a 12V car battery
- ★ 25 ft. cord w/ converter for 110VAC 50/60 Hz operation
- ★ Output jacks for illum. reticle eyepiece and map light
- ★ Equatorial wedge with compass, bubble level, micro metric azimuth control
- ★ Piggyback camera mount for effortless wide-field photography (**Best to photograph Comet Halley!**)
- ★ Audio cassette explains features, set-up, visual & photographic applications

FEATURES OF BOTH 2080/LX2 & 2080/LX3

- ★ Lifetime warranty on telescope, wedge, tripod
- ★ 8"f/10 Schmidt-Cassegrain optics, F = 2000mm
- ★ 20mm Research-Grade Erfle 1¼" eyepiece (100X)
- ★ 7mm Research-Grade Orthoscopic eyepiece (286X)
- ★ High transmission coatings on the front corrector lens
- ★ Ultraprecision 6" LX worm gear motor drive
- ★ Oversize 8.25" primary mirror benefits photography
- ★ Convenient fork mount with slow motion controls
- ★ Best overall mechanical stability of any 8" Cassegrain
- ★ Large right ascension & declination setting circles
- ★ Padded carrying case
- ★ Eyepiece rack
- ★ Lattitude scale and no-tool knob set
- ★ Adjustable height heavy duty tripod with eyepiece rack
- ★ Dew shield & accessory tray, optional **add $88**
- ★ Star map & finder cards for Messier objects
- ★ Red astronomer's night flashlight
- ★ **Optional:** Multi-coated/silvered optics boost transmission 18%, **add $149**

2120/LX3 10" System $2695

The 10" Meade 2120/LX3 collects 56% more light than an 8" telescope for significantly improved viewing and astrophotography. It has all the features of the 2080/LX3 (see above.)

Meade 2120/LX3 w/wedge & tripod ($4500 List)	$2695
Multi-coated/silvered optics boosts transmission 18% Highly recommended!	$195
#710 dew shield (10") Essential!	$98
#36 dual-axis drive corrector control box	$99
#38 declination motor and clutch	$99
LUMICON Giant EASY-GUIDER/Rich-Field viewer for f/4-f/10 operation (state camera)	$359

4" MEADE 2045 w/ table tripod . . .$650

$650

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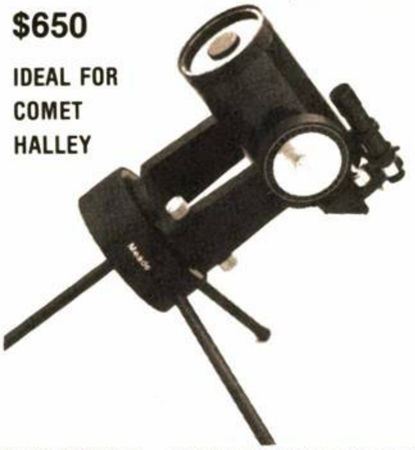

Meade Model 2045 — Advanced engineering and superb optical performance in a beautiful ultraportable system.

FEATURES OF THIS TELESCOPE

- ★ 4"f/10 Schmidt-Cassegrain optics, F = 1000mm
- ★ High transmission coatings on front corrector lens
- ★ Table tripod for easy polar alignment
- ★ 5X24 straight-thru finderscope
- ★ 1¼" right-angle star diagonal
- ★ 1¼" 25mm (40x) and 9mm (111x) eyepieces
- ★ Sturdy fork mount with setting circles
- ★ Manual slow motion controls
- ★ Star map & red astronomer's flashlight

HIGHLY RECOMMENDED OPTIONS

Model 43 drive corrector uses 12VDC ($120 List)	$96
See Meade 2080/LX2 options	
Wedge & field tripod as for 2080/LX2	$298
Dew shield	$45
Solar Filter	$126

80mm REFRACTOR $495

Model 310 ($700 list) $495

Excellent for both terrestrial & astronomical viewing 80mm (3.1") f/11 refracting telescope includes 1¼" focuser, 6x30mm finderscope, 36X and 100X 1¼" eyepieces, adjustable height tripod with accessory tray, and alt-azimuth mount with slow motion controls.

Model 320 ($900 list) $630

Identical to 310, but has equatorial mount with setting circles.

Quartz motor drive	$169
Basic camera adapter	$32
Easy-Guider (state camera)	$149

OPTIONS BOOST PERFORMANCE

LUMICON UHC Filter for nebulae. Standard 1¼"	$79
Prem 1¼", **$99**; Std 48mm, **$149.50**; Prem 48mm	$189.50
LUMICON Deep-Sky Filter, 1¼" Premium	$79
48mm Prem Deep-Sky	**$119.50, $99.95** w/ Easy-Guider
Adapter for viewing w/ 1¼" eyepiece	$20
Dust Covers. Keep optics clean. For 6"	$16/pair
8" . . . . **$20/pair**; 10" . . . . **$18**; 16"	$24
LUMICON Rich-Field Viewer (2080)	$120
LUMICON Newtonian Easy-Guider, 1¼" or 2"	$149
#122 2X Barlow ($60 list)	$48
Dual-axis drive corr. and elec. dec.: for 2080/LX2	$298
for Model 628, 826, DS-10 . . . . . **$310** for DS-16	$420
Tele Vue 32mm Plossl 1¼" eyepiece	$88
LUMICON Cassegrain Easy-Guider for 2080/LX2 & /LX3 (state camera)	$199
Illuminated reticle eyepiece & battery pack	$69.50

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6"f/5 NEWTONIAN $695

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Models 6600 (6"f/5) & **8800** (8"f/4.5) telescopes

Model 6600, 6"f/5 Newtonian telescope ($1100 list)	$695
—Best performance & value; bright, wide views.	
Model 8800, 8"f/4.5 Newtonian Telescope ($1400)	$895
—Collects 78% more light than a 6" telescope.	

These Meade Professional Series reflecting telescopes yield superb rich-field viewing w/ bright images. They include an equatorial mount w/ adjustable tripod, setting circles, slow motion controls, 6x30mm view-finder, 1¼" focuser, 25mm & 9mm 1¼" eyepieces, & accessory tray.

#784 Quartz motor & quartz drive corrector	$169
Basic camera adapter (for moon & planets)	$32
1¼" LUMICON Easy-Guider (state camera)	$149

8"f/6 NEWTONIAN $890

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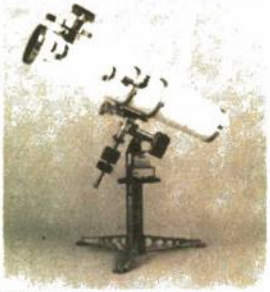

Model 826, 8"f/6 Telescope w/ accessories

Model 628, 6"f/8 with motor drive ($1220 list)	$785
—Best telescope for all visual use, superb optics.	
Model 826, 8"f/6 with motor drive ($1396 list)	$895
—Collects 78% more light than a 6" telescope	
Model 826C, 826 w/ 2" focuser, 8x50mm finder ($1530)	$995

These Meade Deluxe Series reflecting Telescopes have superb image quality at low or high power. They include an equatorial mount with motor drive, pier, legs, setting circles, 1¼" rack & pinion focuser, 6x30mm finderscope, 25mm (48x) and 9mm (135x) 1¼" eyepieces, altitude and azimuth fine adjustments for polar alignment.

#43 drive corrector uses 12VDC ($120 list)	$96
#47M Dual-axis drive corrector & elec. dec.	$340
1¼" or 2" EASY-GUIDER (state camera)	$149

16" f/4.5 NEWTONIAN $1995

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Meade DS-16A with Accessories

The DS Series of 10" and 16" reflecting telescopes are ideal for deep-sky viewing and photography.

DS-10A, 10"f/4.5 with motor drive ($1510 list)	$995
—Gathers 56% more light than an 8" telescope	
DS-16A, 16"f/4.5 with motor drive ($3050 list)	$1995
—Gathers 400% more light than an 8" telescope	

Both the DS-10A and DS-16A telescopes include an equatorial mount, #680 2" focuser, motor drive, setting circles and 25mm 1¼" eyepieces.

6x30mm finderscope with brackets ($46 list)	$39
8x50mm finderscope with brackets ($114 list)	$89

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- Photo Coupler
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Outfit with Minolta X-700	$549.90
Outfit with Nikon FG	$549.90
Outfit with Pentax ME Super	$529.90
Outfit with Olympus OM-PC	$529.90
Outfit with Canon T-50 Motorized	$499.90

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- Ultra precise gear drive

Complete outfit w/Oculars, Finderscope etc. as supplied by the manufacturer.

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Large Assortment of Accessories **IN STOCK!**

SUPER POLARIS C8 w/Super Polaris Equatorial Mount & Adjustable Tripod	**CALL**
COMET CATCHER by Celestron	$265
Comet Catcher Jr	$210
Sky Sensor Computing Control	$392
SP-C102 w/Super Polaris Mount 38X, Dew Cap, Black	$890

C90 SPOTTING SCOPE 7-PC OUTFIT $345

- C90 Scope
- 30mm Ocular
- 18mm Ocular
- Finderscope
- Star Diagonal
- Lens Cap
- Carry Case
- Hi-Tech BLACK

C6 NEWTONIAN w/Eqtrl Mount, Slow Motion Finderscope, Ocular & Tripod **CALL**

C-130 5" Newtonian w/Tripod **$549**

CELESTRON COMETRON SALE

COMETRON 60 w/2 Oculars, Adjustable Tripod, Lens Hood & Finderscope	**CALL**
CO-114 REFLECTOR 4.5" Scope on Eqtrl Mount w/Adjustable Tripod	$349
ZOOM REFRACTOR 20 to 60 Power w/Eyepiece & Tripod #31020	$179
SUPER POLARIS C80 w/Tripod	$599
COMETRON 50 BRASS w/Pedestal	$279
ZOOM MASTER 12-60X Spotting Scope Rubber Coated; Gift Box (Similar to Bushnell Discoverer)	$229

SS-50 Celestron Spotting Scope w/20X Eyepiece, Hi-Tech Black **$149**

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- 40X & 83X Eyepieces Included

#107D (40X & 111X), 1000MM Effect **$399**

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- Best Seller Astronomical Telescope for the Serious Amateur
- Tremendous Light Gathering Capacity
- Hi-Transmission Coating
- Supplied w/Ultra-Precise Drive System to Automatically Track Astronomical Objects

Outfit includes Star Diagonal, 2 Eyepieces 100X & 286X & 8x50 Finderscope **$1149**

#2080/LX3 w/Wedge & Tripod
- Top-of-the-Line: The Ultimate in 8"
- Quartz Electronic Drive System
- Multi-Coated Diagonal Prism **CALL**

REFRACTORS #295 2.4" Equatorial, 900MM, 100X	$329
#320 3.1", 900MM F11, 1¼" O.D., w/Tripod	$489
COMET SEEKER 2.4" Wide Field, w/Tripod & Carry Case	$239.90
6600, 6" Reflector (30X & 85X) w/Tripod	$609
8800, 8" Reflector (37X & 102X) w/Tripod	$799

ZEISS

6x20B Indiv. Focus (IF)			$157
8x20B Center Focus (CF)			$184
8x20/IF	$168	10x25B/CF	$197
8x30B/CF T*	$363	10x40B/CF T*	$437

RUBBER ARMORED:

7x42B/CF/GA T*	$406	7x50B/IF/GA T*	$572
8x30B/IF/GA	$327	8x30B/CF/GA T*	$387
8x56B/CF/GA T*	$517	10x40B/CF/GA T*	$451
15x60CF/GA T* Porro Binocular			$774
30x60B/GA T* Spotting Scope			$564

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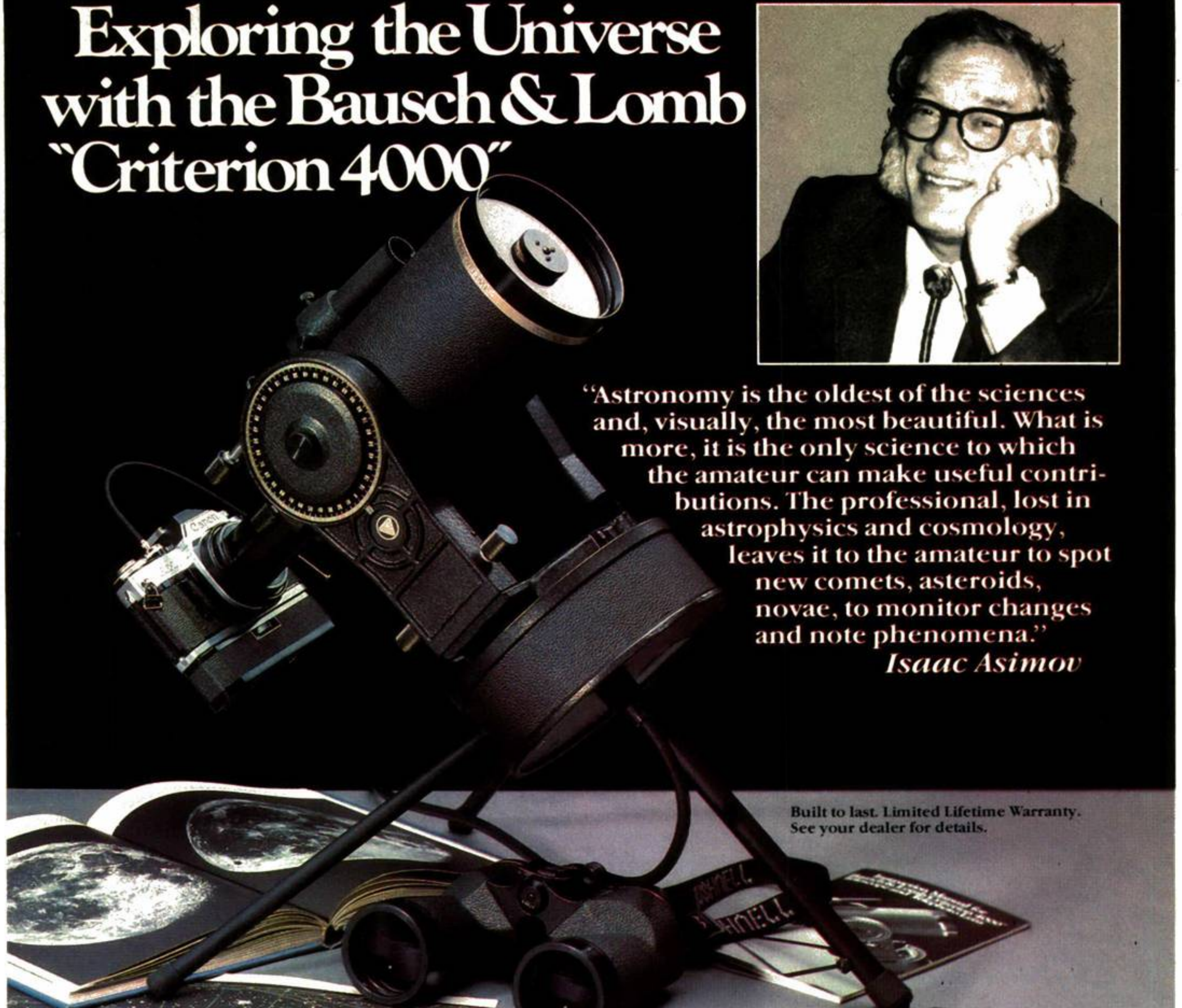

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ASTRONEWS

What Color is Halley's Comet?

By early 1985, Comet Halley had fallen far into the inner solar system, where the increasing heat of the Sun began to boil gas off the surface of its nucleus to create the beginnings of a coma. However, within a very short "window" — just after the nucleus grew bright enough to be visible to Earth-based telescopes but before it was completely hidden by the coma — astronomers made a series of infrared measurements with the 3-meter NASA infrared telescope facility and the 2.2-meter University of Hawaii telescope at Mauna Kea, Hawaii. Astronomers Dale Cruikshank and David Tholen (of the Institute for Astronomy in Hawaii) and William Hartmann (of Arizona's Planetary Science Institute) have now determined the approximate color of the comet's nucleus.

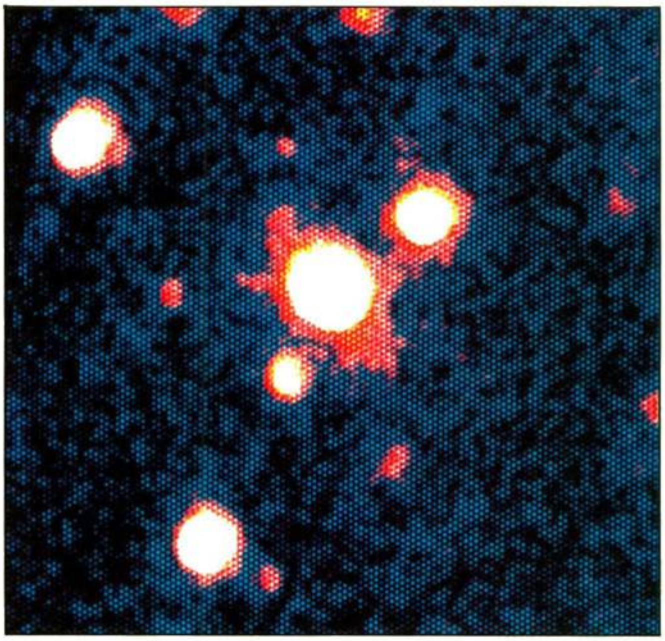
By measuring light from the nucleus through filters at different wavelengths, the scientists compared the number of photons detected at each wavelength. They reported in *Nature* that the closest fit for both their data and that obtained by others is for a very dark, reddish object similar to the coloring of the Trojan asteroids which reside in Jupiter's orbit.

In similar measurements of other small outer solar system bodies, the astronomers found "a range of colors from relatively blue to red, with clumping at the extremes. [This] trend in the colors . . . can be interpreted if outer solar system bodies are composed of mixtures of ice and dark (carbonaceous?) condensates."

Carbonaceous (C-type) asteroids are very black objects that reside mainly in the outer asteroid belt; they are believed to resemble carbonaceous meteorites which contain up to 20% water. D-type objects, such as Jupiter's Trojan asteroids, are similar but redder in color — which other planetary scientists suggest may represent organic material deposited during formation at great distances from the Sun.

Comet Halley and other comets measured by the authors have almost these colors: "No comet observed by us," say Cruikshank, Tholen and Hartmann, "has a color consistent with clean ice, and the majority of them have colors just offset from the D colors." They suggest this color comes from D-type dust, giving the nucleus "the appearance of a D-type asteroid, with a radius of about ten kilometers," or it might possibly be a swarm of D-type particles.

These and other observers have noted changes in the comet's brightness which "have been widely considered as evidence for rotation of an irregularly-shaped nucleus, although no unambiguous period has thus far been established." *Donald F. Robertson.*



In June, astronomers Paul Hintzen of NASA and John Stocke of the University of Arizona announced the discovery of a rotating gas cloud surrounding quasar 3C 275.1. The quasar lies at the center of an extremely rich cluster of galaxies some 2,500 megaparsecs away. The surrounding gas cloud appears to be falling in toward the quasar and being sucked into a gigantic black hole.

Mars Observer Mission Announced

For the first time in several years, NASA is looking for scientists to build instruments for a planetary mission.

On April 8th, the agency issued an "Announcement of Opportunity" (AO) for the Mars Observer mission, formerly called the Mars Geochemical/Climatology Observer mission.

This mission is one of four recommended as a "core program" by the Solar System Exploration Committee, whose findings are the focus of NASA's rebuilt planetary exploration program (see "Return to the Planets," September 1983).

"The primary objective of the Mars Observer mission," NASA says, "will be to make observations that will enhance our understanding of the geosciences and climatology of Mars."

The program was started in the current budget. Launch is scheduled for August or September 1990, with arrival at Mars in August 1991. After arrival in Mars orbit, the spacecraft will be checked out for 80 days while it drifts to a position where its orbit can be changed to one 224 miles high and inclined 93° to the equator. In this orbit, it will cross the martian equator at 2 p.m. local time each day.

The baseline mission is to last 687 days, one martian year. After that — or after an extended mission, depending on the spacecraft's health — the Mars Observer will be boosted to a higher quarantine orbit to prevent it from entering the atmosphere and possibly scattering terrestrial germs on the Red Planet.

In line with the committee's recommendations to use existing spacecraft designs, the Mars Observer's design will restrict the amount of weight and volume available for the science payload.

The "strawman" payload consists of a gamma-ray spectrometer and a visible-infrared mapping spectrometer, a radar altimeter, atmospheric profiler and sounder, ultraviolet photometer, ultraviolet spectrometer, a magnetometer, plus the spacecraft telecommunications system.

Three of these instruments may be included by NASA regardless of whether they are "adopted" by a principal scientific investigator. If flown, these instruments would share their data with all the scientists:

- A gamma ray spectrometer to prospect for potassium, thorium, uranium, hydrogen, oxygen, magnesium, aluminum, silicon, iron, and other elements by looking for gamma rays emitted either by the natural decay of radioactive isotopes of these elements or from secondary radiation scattered back to space by cosmic gamma rays. The resolution of the instrument will be about 120 miles.
- A mapping spectrometer based on the near-infrared mapping spectrometer aboard the Galileo orbiter being built for a mission to Jupiter. It will have 320 spectral channels (colors) and can see between 300 and 4,300 nanometers — possibly down to 5,200 nm if the instrument's range can be extended. (Visible light falls in the 38nm to 78nm range.) The spectrometer's field of view will be a strip about 400 feet wide on the martian surface. With it, scientists will be able to gather data on the mineral and geological make-up of Mars.
- The spacecraft telecommunications system will provide scientists with the opportunity to study the martian atmosphere when the spacecraft passes behind the planet each orbit and its signals are filtered by the thin air.

A pre-proposal briefing was held at the Jet Propulsion Laboratory, the mission manager in Pasadena, California, on May 23, 1985. Proposals were to be received by the close of business on August 2nd. A tentative selection will be made in February 1986. *Dave Dooling.*

Watching a Dying Star

A team of astronomers from the United States, Chile, and Argentina recently reported observing, for the first time, a star in its death throes. The group watched a Type II supernova — designated 1983k — as the mounting explosion formed deep within the star, weeks before it reached the tenuous stellar surface. Although the star's exact type is unknown, it was probably either a red supergiant — thousands of times the size and perhaps seven times the mass of the Sun — or a Wolf-Rayet star.

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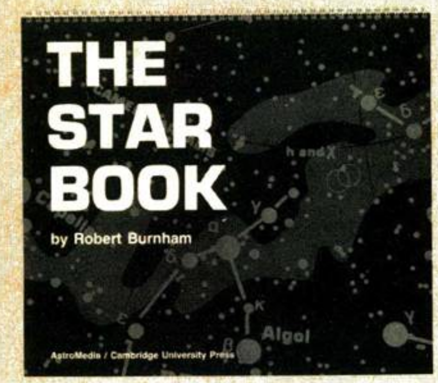

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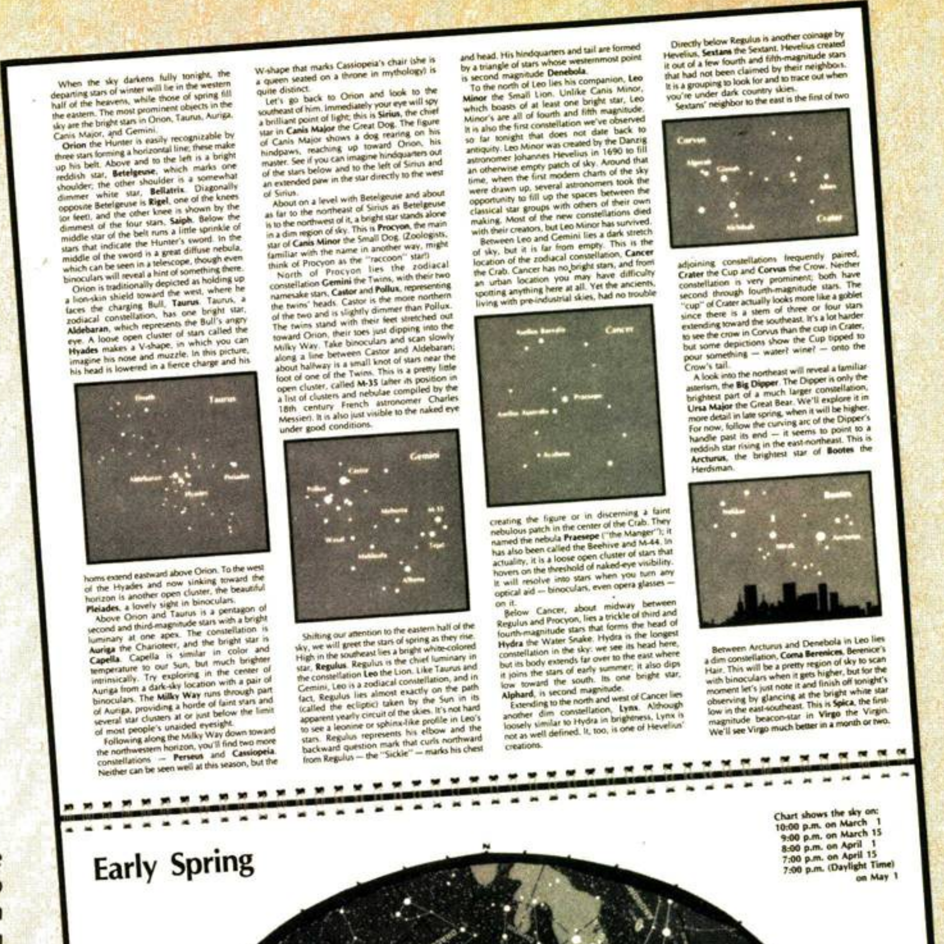

When the sky darkens fully tonight, the departing stars of winter will lie in the western half of the heavens, while those of spring fill the eastern. The most prominent objects in the sky are the bright stars in Orion, Taurus, Auriga, Canis Major, and Gemini.

Orion the Hunter is easily recognizable by three stars forming a horizontal line; these make up his belt. Above and to the left is a bright reddish star, **Betelgeuse**, which marks one shoulder; the other shoulder is a somewhat dimmer white star, **Bellatrix**. Diagonally opposite Betelgeuse is **Rigel**, one of the knees (or feet), and the other knee is shown by the dimmest of the four stars, **Saiph**. Below the middle star of the belt runs a little sprinkle of stars that indicate the Hunter's sword. In the middle of the sword is a great diffuse nebula, which can be seen in a telescope, though even binoculars will reveal a hint of something there.

Orion is traditionally depicted as holding up a lion-skin shield toward the west, where he faces the charging Bull, **Taurus**. Taurus, a zodiacal constellation, has one bright star, **Aldebaran**, which represents the Bull's angry eye. A loose open cluster of stars called the **Hyades** makes a V-shape, in which you can imagine his nose and muzzle. In this picture, his head is lowered in a fierce charge and his horns extend eastward above Orion. To the west of the Hyades and now sinking toward the horizon is another open cluster, the beautiful **Pleiades**, a lovely sight in binoculars.

Above Orion and Taurus is a pentagon of second and third-magnitude stars with a bright luminary at one apex. The constellation is **Auriga** the Charioteer, and the bright star is **Capella**. Capella is similar in color and temperature to our Sun, but much brighter intrinsically. Try exploring in the center of Auriga from a dark-sky location with a pair of binoculars. The **Milky Way** runs through part of Auriga, providing a horde of faint stars and several star clusters at or just below the limit of most people's unaided eyesight.

Following along the Milky Way down toward the northwestern horizon, you'll find two more constellations — **Perseus** and **Cassiopeia**. Neither can be seen well at this season, but the W-shape that marks Cassiopeia's chair (she is a queen seated on a throne in mythology) is quite distinct.

Let's go back to Orion and look to the southeast of him. Immediately your eye will spy a brilliant point of light; this is **Sirius**, the chief star in **Canis Major** the Great Dog. The figure of Canis Major shows a dog rearing on his hindpaws, reaching up toward Orion, his master. See if you can imagine hindquarters out of the stars below and to the left of Sirius and an extended paw in the star directly to the west of Sirius.

About on a level with Betelgeuse and about as far to the northeast of Sirius as Betelgeuse is to the northwest of it, a bright star stands alone in a dim region of sky. This is **Procyon**, the main star of **Canis Minor** the Small Dog. (Zoologists, familiar with the name in another way, might think of Procyon as the "raccoon" star!)

North of Procyon lies the zodiacal constellation **Gemini** the Twins, with their two namesake stars, **Castor** and **Pollux**, representing the twins' heads. Castor is the more northern of the two and is slightly dimmer than Pollux. The twins stand with their feet stretched out toward Orion, their toes just dipping into the Milky Way. Take binoculars and scan slowly along a line between Castor and Aldebaran; about halfway is a small knot of stars near the foot of one of the Twins. This is a pretty little open cluster, called **M-35** (after its position in a list of clusters and nebulae compiled by the 18th century French astronomer Charles Messier). It is also just visible to the naked eye under good conditions.

Shifting our attention to the eastern half of the sky, we will greet the stars of spring as they rise. High in the southeast lies a bright white-colored star, **Regulus**. Regulus is the chief luminary in the constellation **Leo** the Lion. Like Taurus and Gemini, Leo is a zodiacal constellation, and in fact, Regulus lies almost exactly on the path (called the ecliptic) taken by the Sun in its apparent yearly circuit of the skies. It's not hard to see a leonine or sphinx-like profile in Leo's stars. Regulus represents his elbow and the backward question mark that curls northward from Regulus — the "Sickle" — marks his chest and head. His hindquarters and tail are formed by a triangle of stars whose westernmost point is second magnitude **Denebola**.

To the north of Leo lies his companion, **Leo Minor** the Small Lion. Unlike Canis Minor, which boasts of at least one bright star, Leo Minor's are all of fourth and fifth magnitude. It is also the first constellation we've observed so far tonight that does not date back to antiquity. Leo Minor was created by the Danzig astronomer Johannes Hevelius in 1690 to fill an otherwise empty patch of sky. Around that time, when the first modern charts of the sky were drawn up, several astronomers took the opportunity to fill up the spaces between the classical star groups with others of their own making. Most of the new constellations died with their creators, but Leo Minor has survived.

Between Leo and Gemini lies a dark stretch of sky, but it is far from empty. This is the location of the zodiacal constellation, **Cancer** the Crab. Cancer has no bright stars, and from an urban location you may have difficulty spotting anything here at all. Yet the ancients, living with pre-industrial skies, had no trouble creating the figure or in discerning a faint nebulous patch in the center of the Crab. They named the nebula **Praesepe** ("the Manger"); it has also been called the Beehive and M-44. In actuality, it is a loose open cluster of stars that hovers on the threshold of naked-eye visibility. It will resolve into stars when you turn any optical aid — binoculars, even opera glasses — on it.

Below Cancer, about midway between Regulus and Procyon, lies a trickle of third and fourth-magnitude stars that forms the head of **Hydra** the Water Snake. Hydra is the longest constellation in the sky: we see its head here, but its body extends far over to the east where it joins the stars of early summer; it also dips low toward the south. Its one bright star, **Alphard**, is second magnitude.

Extending to the north and west of Cancer lies another dim constellation, **Lynx**. Although loosely similar to Hydra in brightness, Lynx is not as well defined. It, too, is one of Hevelius' creations.

Directly below Regulus is another coinage by Hevelius, **Sextans** the Sextant. Hevelius created it out of a few fourth and fifth-magnitude stars that had not been claimed by their neighbors. It is a grouping to look for and to trace out when you're under dark country skies.

Sextans' neighbor to the east is the first of two adjoining constellations frequently paired, **Crater** the Cup and **Corvus** the Crow. Neither constellation is very prominent; both have second through fourth-magnitude stars. The "cup" of Crater actually looks more like a goblet since there is a stem of three or four stars extending toward the southeast. It's a lot harder to see the crow in Corvus than the cup in Crater, but some depictions show the Cup tipped to pour something — water? wine? — onto the Crow's tail.

A look into the northeast will reveal a familiar asterism, the **Big Dipper**. The Dipper is only the brightest part of a much larger constellation, **Ursa Major** the Great Bear. We'll explore it in more detail in late spring, when it will be higher. For now, follow the curving arc of the Dipper's handle past its end — it seems to point to a reddish star rising in the east-northeast. This is **Arcturus**, the brightest star of **Bootes** the Herdsman.

Between Arcturus and Denebola in Leo lies a dim constellation, **Coma Berenices**, Berenice's Hair. This will be a pretty region of sky to scan with binoculars when it gets higher, but for the moment let's just note it and finish off tonight's observing by glancing at the bright white star low in the east-southeast. This is **Spica**, the first-magnitude beacon-star in **Virgo** the Virgin. We'll see Virgo much better in a month or two.

Early Spring

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object, this marks the first observation of the ultimate fate of these unusual stars. As helium-burning descendants of the most massive stars in the universe, Wolf-Rayet stars are hypothesized to act as fuses that sizzle for a brief half-million years before violently exploding in a supernova blast.

In any case, the data acquired using telescopes at La Serena, Chile represent a unique find. Normally, astronomers see supernovae only during their brief, violent terminations; little is known about the preceding conditions. The team of astronomers observed 1983k for two weeks prior to the explosion and obtained a clear view of the progenitors of Type II supernovae.

The first detection of something unusual occurred on June 6, 1983 in Santiago, where astronomer Marina Wischnjewsky was photographing galaxy NGC-4699 as part of a regular supernova patrol program. Having spotted an unusual star near the galaxy, she called Maria Teresa Ruiz, a visiting astronomer at Cerro Tololo Observatory at La Serena. Ruiz, together with astronomers Mark M. Phillips and Virpi S. Niemela, published the results of their observations in a recent issue of *Astrophysical Journal*.

Said Phillips, the discovery couldn't have been made at a better time. "It was serendipitous that we had this team of experts at Cerro Tololo," he says. "Maria Teresa specializes in supernova remnants, and Virpi is a specialist in Wolf-Rayet stars."

The team made three spectra of NGC-4699 — a galaxy some 13 megaparsecs distant — on June 14, 16, and 17, using an electronic light detector mounted on the spectrograph of the 1.5-meter telescope at Cerro Tololo. Meanwhile, additional measurements were made using the Yale telescope at Cerro Tololo, the 0.7-meter telescope at Cerro Roble Observatory, and Cerro Tololo's 4-meter reflector. From these data, the astronomers calculated this scenario:

- June 6, 1983: The star, probably a red supergiant, is seven times as massive as the Sun. About 1.5 solar masses of its material are dispersed in an enormous envelope reaching outward for 5.7 billion miles — 13,300 times the radius of the Sun. Although the star is now 300 times as brilliant as it was only a few weeks before and continues brightening, the impending explosion is not yet evident in any way at the star's surface. Deep within the star, however, nuclear fuel is spent and the core — barely one thousand miles in diameter — has collapsed. A shock wave produced by the collapse is just over halfway to the star's surface. The star-death has begun.
- June 14: Spectra show several strong, broad emission lines superimposed on a bluish continuum — the distinctive "signature" of a Wolf-Rayet star rich in nitrogen and helium. As the astronomers report, "The strong Wolf-Rayet-like spectra seen in the first premaximum observations represent a hitherto unobserved phase in the development of Type II supernovae." The star's radius is the same as on June 6th, but the detonation shock wave — moving outward at 1500 miles per second — is now more than 80% of the way to the surface. The death struggle continues.
- June 23: 1983k reaches maximum light. The distinctive Wolf-Rayet emission abruptly vanishes. Now narrow hydrogen lines appear — dark lines in the spectrum indicating neutral hydrogen between the light source and the observer. The Chilean team believes this is probably evidence of a large circumstellar shell — either the envelope of a red supergiant or material stripped from a Wolf-Rayet star. The detonation shock wave has nearly reached the star's surface. The star has begun to expand explosively: its diameter jumps by some 50 million miles. The death struggle is nearly over.
- Late July: The explosion stretches the radius of the destroyed star to nearly 8 billion miles. Soon 1983k will become a nebula, the dusty, dead remains of a once active star.

The astronomers conclude "that supernova 1983k most likely resulted from a massive star with an extended envelope, which had undergone significant mass loss prior to exploding and whose layers contained nitrogen-rich material." Whether or not the star was a Wolf-Rayet object, they note, remains to be tested in theoretical models.

Spacelab 3 Experiment Creates a "Planet in a Test Tube"

An experiment to build a "planet in a test tube" on Spacelab 3 not only worked as planned, but apparently generated its own miniature "Red Spot" during its last test run according to scientists involved in the project.

"There's a whole zoo of things in there, so we're really excited," said Dr. John Hart of the University of Colorado. Hart was the principal investigator for the geophysical fluid flow cell (GFFC), one of several experimental facilities aboard the Spacelab 3 mission flown April 29 to May 6, 1985.

The GFFC simulated the atmospheres of Jupiter and the Sun to conduct experiments in fluid flow that are not possible on Earth. The cell had a 1.9-inch inner sphere, made of steel and coated with gold, nested in a 2.6-inch sapphire outer sphere, leaving 0.7-inch of depth for the "atmosphere" of silicone oil. In addition, the inner sphere was heated from inside as are the Sun and Jupiter (the Sun by nuclear fusion, Jupiter and Saturn by the sheer weight of the atmosphere crushing whatever is at the core).

The heaters inside the hemisphere and on the dome provided equator-to-pole changes to mimic the heating patterns seen on Jupiter and the Sun. The cell rotated up to once every 30 seconds because rotation is an important part of atmospheric circulation. An ultraviolet lamp then flashed the silicone oil to darken a photochromic dye that works on the same principle as sunglasses which darken outdoors. This created a dot pattern that was photographed. Changes in density were seen by measuring how much a pattern called a Ronchi ruling seemed to bend when its image passed through the oil.

Such experiments are impractical on Earth because gravity will set up convection currents that cause warm fluid to rise and cold to settle. Only limited success has been had with cylindrical models. But in the weightlessness of space, the oil was expected to flow around the metal hemisphere in the same manner as that of the giant gas planets or the Sun, and thus lead to an understanding of how those atmospheres operate.

Film from the last test run, which had the lowest priority, was developed within a week of landing to make sure there would be no problems in processing the other reels. Already Hart and co-investigator Frank Leslie of Marshall Space Flight Center have found what appear to be jovian structures in their "planet in a test tube."

In the experiment, conditions were set to imitate the banded patterns that girdle Jupiter. "And indications are one of the experiments produced those," Hart said. "But they were transitory and gave way to another class of motion," a pole-to-equator flow called "banana cells" because that is what they look like. Banana cells are a common structure in the Sun's atmosphere.

"But the real surprising thing is that the circulation, instead of being uniformly turbulent or nicely uniformly structured," Hart said, "actually broke down across the face of the sphere and produced isolated eddies that look a lot like the jovian Red Spot." A sampling of frames from the 16mm data film — which has annotations on the side to indicate conditions at the time — clearly shows a swirl, almost like a vortex, near the pole.

The swirl that appears on the GFFC film bears a strong resemblance to Jupiter's Red Spot, even down to vortex shedding — a snakelike flow downwind from the spot (vortex shedding is what makes flags flap in the wind). But proof that the two have similar origins and lives must await detailed analysis of the data and photos.

One factor to be considered in that analysis is the difference in size between the GFFC and the subjects it models. "These experiments are probably at much smaller Rayleigh numbers than appropriate for planetary atmospheres," Hart said. The Rayleigh number is a dimensionless number that is a function of buoyancy, depth, temperature difference, viscosity, and other factors.

The difference between the GFFC and the planets is at least a factor of 10. "On the other hand," Hart continued, "it is substantially larger — a million times larger — than anything you could possibly hope to compute with a Cray [supercomputer]," he added. "So, this is a unique data set that provide good data . . . and will guide our thinking." But digesting the 50,000 frames of film shot in the GFFC experiments is itself a mammoth task requiring a computer.

Hart expects the GFFC to bring the field of geophysical flows a major step forward. "Certainly, prior to this there has been no experiment that will give any indication of fluid flow over a sphere," he said. "We should have some major discoveries here that are of great interest." Meanwhile, GFFC is slated for reflight on the International Microgravity Lab in 1987.

The success of the GFFC also proves that a similar Atmospheric General Circulation Experiment, proposed by Dr. William Fowlis of Marshall, would be able to simulate the atmosphere of Earth and other inner planets. *Dave Dooling.*

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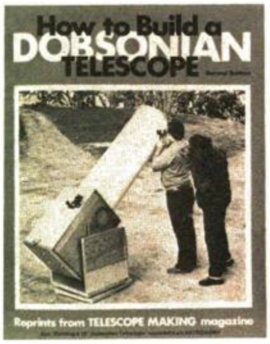
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ASTRO NEWS

Quiet Stars Aren't So Quiet

According to Mark Giampapa of NOAO's National Solar Observatory, active regions similar to solar flares long known to cover hot stars emitting intense radiation, also appear to cover many cool stars. This notion contradicts the conventional view of how these active regions occur and interact with a star's atmosphere. The shapes taken by these regions — bright areas called *plages* (from the French word for beach) and darker areas resembling sunspots — are unlike those observed on the Sun and on other stars, where flare activity appears closely linked to such magnetic-field features.

Giampapa recently described his calculations of activity on cool, supposedly quiet, M-type dwarf stars — stars at the cool end of the main sequence. Based on spectroscopic measurements of different types of M stars, Giampapa estimated the amount of surface covered by active regions. "Dynamo theory predicts that rapidly rotating stars should have more activity than slowly rotating ones," he explains, "and that if you don't measure strong X-ray emission you don't have much surface covered by active regions. Emitting stars rotate rapidly, at perhaps 10 kilometers per second or more, while the others rotate more slowly, at about the same velocity as the Sun . . . about 2 kilometers per second. "But these new calculations, combined with observational data, indicate that the slowly rotating M stars that have a relatively low level of hard-radiation emission are nevertheless widely covered by active regions. Dynamo theory is going to have to tell us why this occurs when the star is rotating slowly."

Giampapa's calculations raise the question of why, if widely covered with active regions, M dwarf stars without hydrogen-alpha emission show no evidence of the enormous spots found on their emitting cousins.

Ideas about chromospheric and atmospheric heating are also affected because hydrogen-alpha emitting stars have hotter — or denser — outer atmospheres than non-emitting ones. "If the non-emitting M dwarfs have so much activity, why don't they heat up?" asks Giampapa.

M dwarf stars are cool enough at the surface — less than 3500 Kelvins — to permit astronomers to work in the hydrogen-alpha region of the spectrum. "In solar type stars," Giampapa explains, "heating of the star fills the hydrogen-alpha *absorption* line with emission, so that you can't tell if you're seeing intense radiation from one violently active region or moderate radiation from many small ones."

Spectroscopic measurements of hydrogen-alpha absorption permit observers to discriminate between huge regions and clumps of many small ones, and help to estimate the amount of surface covered by activity in the star's magnetic texture. "In cool dwarfs, hydrogen-alpha has the property that it appears as an absorption line when you have heating in the stellar atmosphere," says Giampapa. "Because the star's atmosphere isn't hot enough to ionize the hydrogen and boost it to a higher energy level, the absorption line is weak to begin with. Then, if you add heating from disturbances in the magnetic field, the absorption deepens, and finally, with increased heating, begins to fill the emission."

The "filling factor" reflects the amount of surface area covered by activity. For non-emitting M dwarfs, a 10 percent dip in the spectrum representing hydrogen-alpha absorption represents at least 10 percent coverage of the star's surface.

Giampapa concludes that the hydrogen-alpha emitting and non-emitting M stars are "fundamentally similar" in terms of the amount of surface area covered by active regions. But the emitting stars, he figures, must have sites of especially intense activity giving rise to the observed radiation from the chromosphere and corona.

The activity deduced for M stars is fairly minimal. Giampapa estimates that an M star's activity without hydrogen-alpha emission is much like that of the Sun, which offers important clues about the internal workings and magnetic-field structure of M stars as well as earlier main sequence stars. "If we can find [in M stars] an absorption line that behaves like hydrogen-alpha at high stellar surface temperatures," Giampapa notes, "we can do this with other stars."

ASTRO CALENDAR

September 13-15
Astrofest, Chicago, Illinois. Contact: Astrofest, P.O. Box 596-A, Tinley Park, IL 60477. Phone Jon Nehls at (312) 385-3473 or John Phelps at (312) 532-2968.

September 13-15
"The Conjunction" sponsored by the Connecticut River Valley Amateur Astronomers, Northfield Mountain Environmental Center, Northfield, Massachusetts. Contact: Jack Megas, 311 Surrey Rd., Springfield, MA 01118.

September 28
Ohio Turnpike Astronomers Association Convention, The University of Akron, Akron, Ohio. Contact: Philip Hegenderfer, 5070 Manchester Rd., Akron, OH 44319. Phone (216) 644-0230.

Meeting notices to appear in AstroCalendar must be submitted at least four months in advance of the meeting date. Most organizations appreciate your enclosing a long (business-size) self-addressed, stamped envelope along with your request for information.

October 5
Herstmonceux 85, 5th Annual Convention of the British Federation of Astronomical Societies, Herstmonceux Castle, East Sussex, England. Contact: Ken Marcus, 5 Cedars Gardens, Brighton, East Sussex, England BN1 6YD.

October 5
Astro-Assembly, Seagrave Memorial Observatory, North Scituate, Rhode Island. For information, send SASE to: Charles J. Lord Jr., 126 Fair St., New Bedford, MA 02740.

October 5
Telescope Users Clinic, Whittier College, Whittier, California. Contact: Bob Ferguson, Western Observatorium, 13215 E. Penn St., Suite 411, Whittier, CA 90602. Phone (818) 795-4181.

October 10-12
Joint Meeting of the Rocky Mountain Planetarium Society and the Pacific Planetarium Association, Hansen Planetarium, Salt Lake City, Utah. For information, send SASE to: RMPA Meeting, P.O. Box 3023, Boulder, CO 80307.

October 17-20
Okie-Tex Star Party, sponsored by the Oklahoma City Astronomy Club, Lake Murray, Oklahoma. Contact: Joe Pearson, 700 Teal Pl., Edmond, OK 73034.

October 18-20
7th Annual Astronomy Jamboree, Custer Institute, Southold, L.I., New York. Contact: Tom Carey, Vanderbilt Planetarium, Centerport, NY 11721. Phone (516) 757-7502.

November 7-8
SPACE STATION: Gateway to Space Manufacturing and Services, Orlando, Florida. Contact: Anne Phelan, *Space Business News*, 1401 Wilson Blvd., Suite 910, Arlington, VA 22209. Phone (703) 528-1244 or (800) 424-2908.

November 9-10
Deep South Regional Stargaze, Percy Quin State Park, McComb, Mississippi. Contact: Frank W. Loflin II, ALCOR, Jackson Astronomical Association, 280 W. Lorenz Blvd., Jackson, MS 39213. Phone (601) 982-2388 days or (601) 856-3636 evenings.

ANNOUNCEMENT — Attention New York and Long Island stargazers! The Amateur Observers' Society of New York meets the first Sunday of each month at the Vanderbilt Planetarium, Centerport, New York. We always have plenty of room for beginners. For details, phone Barry at (516) 541-1690 evenings.

ANNOUNCEMENT — The Highlands Deep Sky Academy is looking for active members to found a public observatory (to be based in Waywayanda State Park, New Jersey) and fight light pollution. For details, write Michael McGrath, P.O. Box 129, Hewitt, NJ 07421.

ANNOUNCEMENT — All persons in the Moncton, New Brunswick area are welcome to join the Moncton Astronomical Society. For further information, contact Danny Attis, 45 Fairview Dr., Moncton, N.B., Canada E1E 3C8. Phone (506) 854-3811 or (506) 576-7862.

ANNOUNCEMENT — The Westport Astronomical Society invites southern Connecticut stargazers to join us for meetings on the third Tuesday of each month. You'll find us at either the Nature Center (Woodside Lane) or Rolnick Observatory (Bayberry Lane). Call Tom for details at (203) 375-0725.

ANNOUNCEMENT — The Shreveport Astronomical Society invites Ark-La-Tex astronomers to attend our meetings on the third Saturday of each month at 7:30 p.m. on the LSU-S campus, Science Lecture Auditorium. For more information, contact Mark Fletcher, 738 Livingston, Shreveport, LA 71107. Phone (318) 222-6730.

ANNOUNCEMENT — Planetarium internship; bachelor's degree and planetarium experience required; $9,000 stipend plus benefits. Deadline for applications September 15, 1985. For details write: Intern Program, American Museum-Hayden Planetarium, 81st St. and Central Park West, New York, NY 10024.

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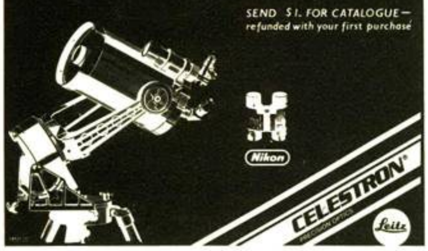

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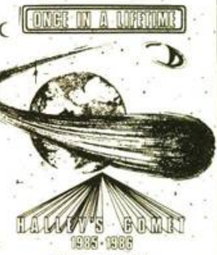

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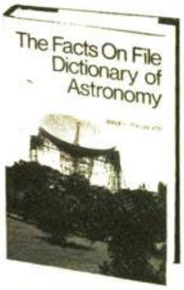

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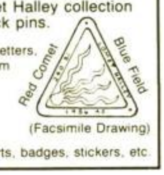

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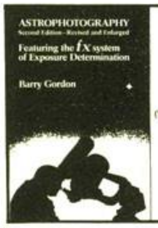
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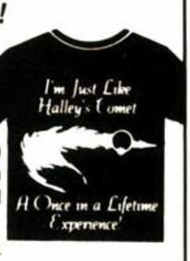
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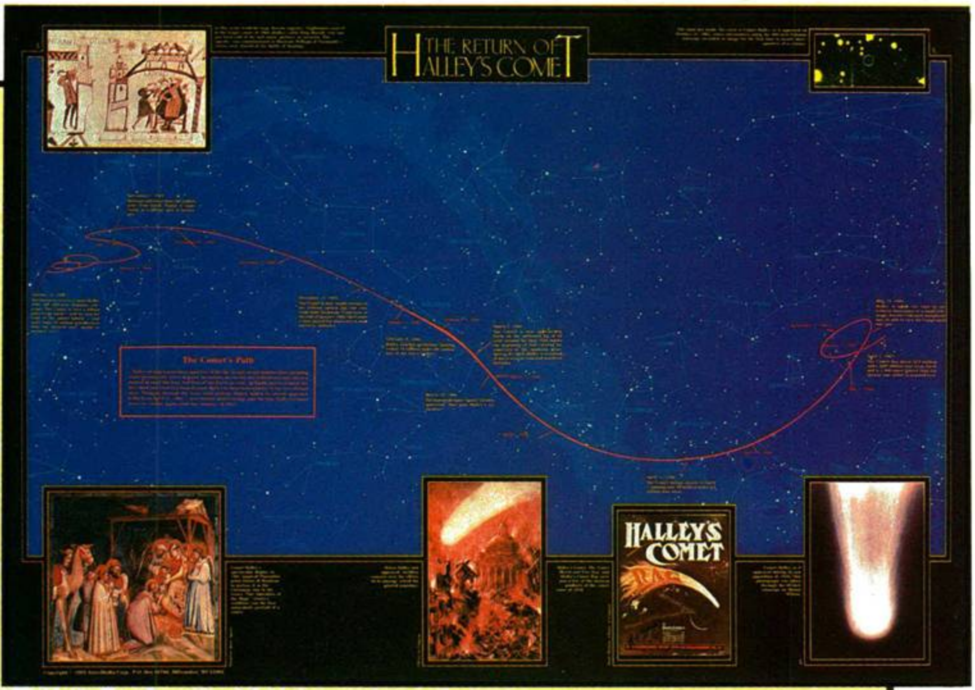

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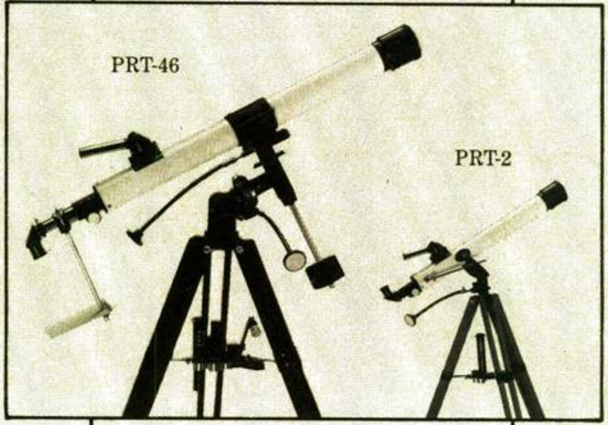

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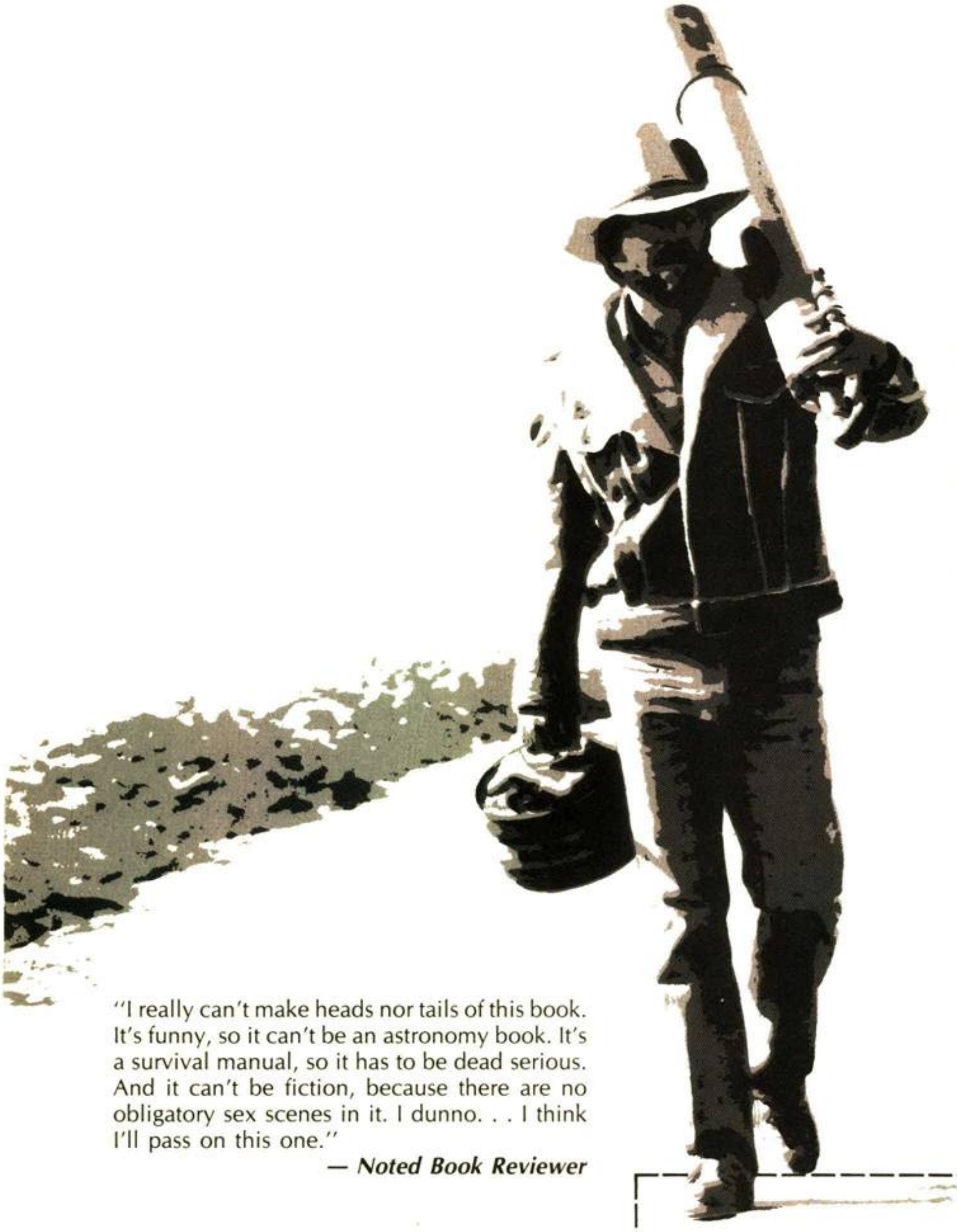

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Breezes, Bangs, & Blowouts: Stellar Evolution Through Mass Loss

by David Darling

Part 1

Imagine you're an exobiologist, newly arrived on the fourth planet of Epsilon Eridani. No world in the Galaxy has such a bizarre assortment of natives, yet only two facts are known about them. First, they're very long-lived. And second, despite their broad array of morphologies, they're all members of the same species.

Your mission is to explain the diversity. Are the differences genetic? In other words, are the aliens born with an enormous range of different characteristics which they then carry through life? Or is the diversity due to changes that occur as the natives grow older? Could it perhaps be a combination of factors — inherent differences plus others brought about by aging and the environment — that causes the Epsilon Eridanians to look so unlike each other? Clearly, a sticky problem. And it's compounded by the fact that the aliens age almost imperceptibly, even over long periods of time.

In reality, stellar evolutionists find themselves in a similar situation. The objects of their study — the stars — rival our imaginary aliens in their array of appearances and behaviors. Properties like stellar size, mass, temperature, and luminosity vary tremendously. Their behavior runs the gamut from almost total quiescence to explosive, cataclysmic activity. Yet, as in our story, catching a star in the act of changing — witnessing a major evolutionary event — is very rare. Why?

Stars can survive for many hundreds, or thousands, of millions of years. Even the most transient — the super-heavyweights with masses dozens of times greater than our Sun — endure for at least several million years. By comparison, human lifetimes are extremely short and the chance that we'll see a given star "do anything" is correspondingly very small.

But the situation's far from hopeless. The Galaxy boasts about one hundred billion stars, all in various stages of evolution and many within the grasp of present-day instruments. By studying this huge and diverse collection of objects in our cosmic backyard, we can not only build a general composite picture of stellar evolution but can in a number of cases actually see vital transient events taking place within individual stars.

Studies of the properties of stars in statistically large groups form the basic cornerstone for our theories of stellar evolution. Yet building detailed models for the life cycles of different types of stars using this kind of "static" information is extremely difficult and tedious. It's like trying to accurately reconstruct several different motion pictures from a randomly-ordered pile of individual frames. (Actually, the situation is worse than this — we have to reconstruct evolutionary sequences for which certain key frames are missing.)

When stars take major evolutionary steps right in front of our instrument-enhanced eyes, however, they reveal much more clearly their underlying structure and physical processes. It's as if, among our confusing pile of frames, we have several brief sequences that link key phases of the plot.

What does all this have to do with our title? Simply this: most rapid stages in the evolution of stars involve some kind of mass ejection — the star throwing off part of itself. By "rapid," we mean anything from a few days to a few million years. The mass ejection might be explosive, or it might be gentle and continuous over relatively long periods. Whatever the rate, total mass loss can be very significant, accounting for a major portion of the star's original mass.

Some of the mass-loss phenomena are related — they can occur in the same star at various stages of its evolution, or in different stars that bear a strong family resemblance. We'll attempt to compare and contrast the various mass ejection mechanisms as we proceed. To begin, though, let's consider the likely future evolution of a star of special importance to us: the Sun.

Sun-Like Stars, and the Formation of Planetary Nebulae

How will the Sun die? What will happen as its supply of nuclear fuel begins to run out? We needn't feel threatened by the question. No global evacuation in some hastily-constructed Space Ark is called for within our lifetimes, or quite possibly even the lifetime of our species. At present, the Sun is enjoying a stable and leisurely middle age which will persist for perhaps another 5 or 6 billion years. Although the Sun's mass drops by some 4 million tons every second — a consequence of the nuclear fusion process — its central reserves of energy-rich hydrogen are plentiful.

But the Sun will eventually exhaust its fuel, as will all stars currently in the core-hydrogen-burning, or "main sequence," stage of their evolution. What happens then?

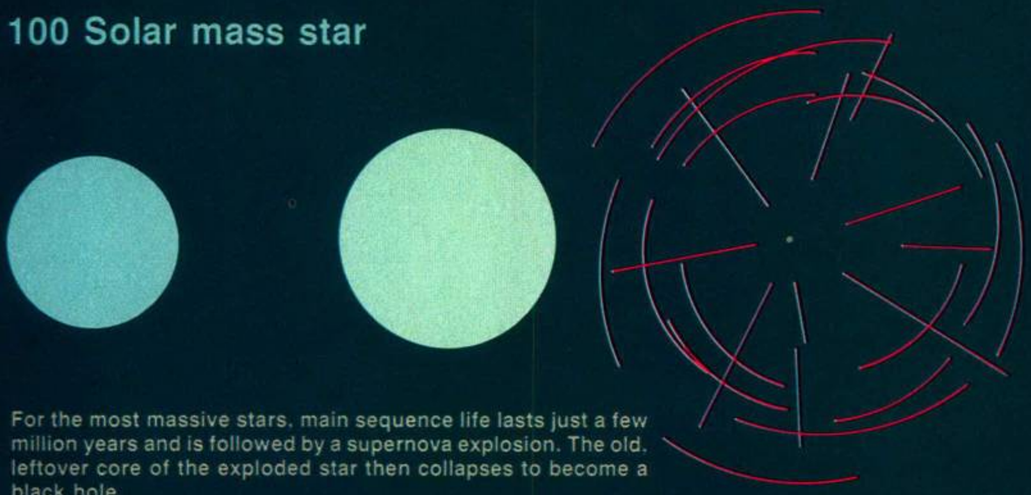
Curiously enough, in many cases the manner of a star's death is pretty much determined even before the first hydrogen nuclei fuse within the star's embryonic core. Mass is the critical factor that controls stellar evolution and largely preordains the ultimate fate of a star. A star's mass is established very early in its protostar stage by the amount of matter that its gravity can suck in from its surroundings.

A star that attains high mass during its formation period is likely to lead a spectacular, if brief, life. Its great weight raises the central core temperature to the point where nuclear fusion processes occur extremely rapidly. The star makes a lot of energy, burns its copious reserves of fuel very quickly, and races through its main sequence phase at breakneck speed. The final act of a massive star can involve the most violent mass-loss process of all — a supernova explosion.

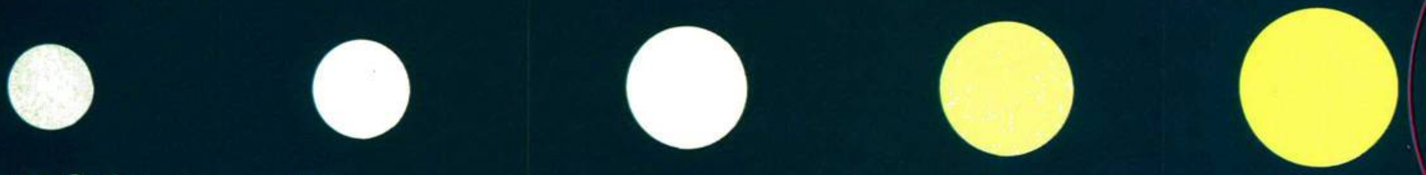
Such a dramatic end, be assured, does not lie in store for our own modest Sun. Lighter-weight stars, having between 1 and

In the Eta Carinae Nebula is a supermassive star which may explode in a colossal "bang" — a supernova — within the next thousand years. Cerro Tololo Inter-American Observatory photo.

100 Solar mass star

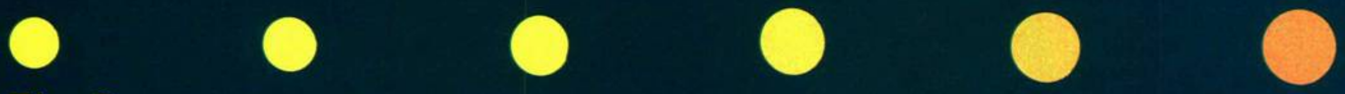


For the most massive stars, main sequence life lasts just a few million years and is followed by a supernova explosion. The old, leftover core of the exploded star then collapses to become a black hole.

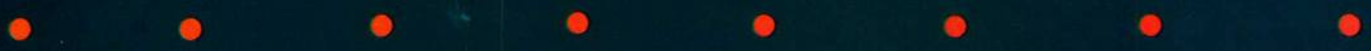


10 Solar mass star

Less-massive large stars may dwell for tens of millions of years on the main sequence, but cannot escape going supernova. The core typically shrinks to become a fast-spinning pulsar.

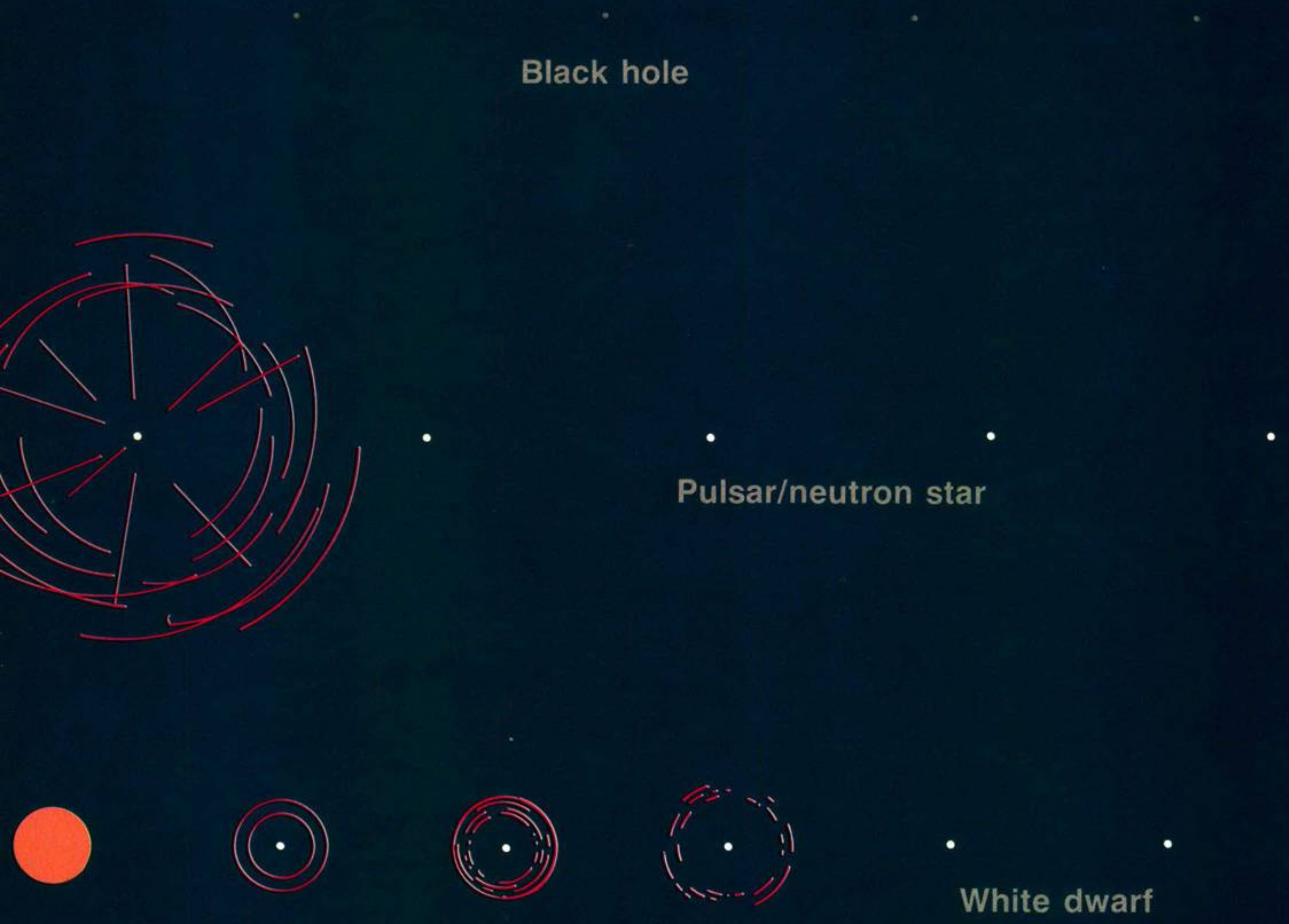


The Sun



0.3 Solar mass star

Endpoints of Stellar Evolution



Five billion years old now, the Sun's main sequence lifetime will probably continue another 10 billion years. Then the Sun will swell to become a red giant and shed a planetary nebula. When the nebula has dissipated, a white dwarf star will remain.

Small red dwarf stars — perhaps the most numerous type of stars in the Galaxy — remain on the main sequence, unchanged, as they have during most of the entire history of the universe.

Mass Loss Process	**Evolution Stage**	**Total Mass Lost** ($M_\odot$)	**Duration** (yrs)	**Peak Loss Rate** ($M_\odot$/yr)	**Initial Ejection Speed** (km/sec)
Planetary Nebula	Shell-burning red giant	10^{-3} to 10 (average 0.2)	Probably short	High	20 to 50
Stellar Wind					Up to several thousand
Massive O-type	Early main sequence	Up to 10	10^5 to 10^7	10^{-4}	
Wolf-Rayet	Post red giant?	Up to 10	10^5 to 10^6	10^{-3}	
Red giant	Following coronal disappearance	Up to 10	10^6 (high mass) to 10^9 (low mass)	10^{-5}	
Sun	Main sequence	10^{-4}	10^{10}	10^{-14}	
Supernova					Up to 10,000
Type I	White dwarf to neutron star collapse	Up to 1?	Very short	Very high	
Type II	Highly-evolved supergiant (iron core 1.4 $M_\odot$)	Up to 10	Very short	Very high	
Nova	White dwarf surrounded by accretion disk, in close binary	10^{-4}	Very short	Very high	Up to several thousand

4 solar masses, pursue a more sedate main sequence course and eke out their moderate reserves of hydrogen fuel over far longer periods.

Nevertheless, Sun-like stars do pass through phases, albeit on a smaller scale, similar to those experienced by their heavyweight cousins. In particular, these less massive stars eventually become red giants when their core supply of hydrogen expires. How do red giants — huge, low-density, low-temperature objects — form from normal main sequence stars like the Sun?

Let's pick up the story of a roughly solar-sized star following the exhaustion of its central hydrogen fuel reserves — i.e., the Sun about 5 billion years from now. Although the star still has much unburned hydrogen in its outer parts, it cannot — in the absence of very strong convective currents — circulate that useful fuel down into its core for fusion. Starved of fuel, energy production at the core shuts down: the temperature there is insufficiently high, as yet, to ignite the large accumulated stocks of helium.

With no radiation pressure to buoy it up, the star's central region (including the core) begins to collapse under the weight of the overlying layers. In the process, it releases gravitational energy. Exactly 50% of this new energy goes into radiation from the star's surface, while the remaining 50% drives a stellar central heating system that radically alters the star's external appearance.

Heat migrating outwards from the gradually collapsing core causes the star's entire atmospheric envelope to expand enormously. A star like the Sun can, over a few hundred million years, grow to around 100 times its original diameter — vaporizing any planets whose orbits it happens to engulf. The star becomes a red giant: "red" because its surface layers have cooled through expansion to a ruddy 3000 Kelvins or thereabouts, and "giant" because it is so large.

In the transition phase from main sequence star to red giant, however, a very peculiar event occurs. While in the so-called "sub-giant" stage, and with its surface temperature at a critical value just below 4500 K, the star quite suddenly loses its corona — its high-temperature outer atmospheric layer.

No one is yet sure why the corona vanishes in such an abrupt manner. But what is clear, based on observational evidence, is that sub-giant stars which have lost their coronas begin to expel matter vigorously in the form of strong stellar "winds." It's possible that radiation previously pumped into the corona (and sustaining very high temperatures there) now expels surface material into space. On the other hand, powerful magnetic fields may also provide the mechanism for mass loss (see "Caution: High Winds Beyond This Point," ASTRONOMY, January 1982). Theoretical understanding of the coronal disappearance and stellar wind mechanism in red giants is still very limited.

We'll return to the subject of mass loss through stellar winds later. For now, let's focus on the events taking place deep in the interior of a star as it evolves to the red giant stage. Remember that the central regions are still contracting gravitationally and releasing energy. At this stage, the temperature around the periphery of the core where hydrogen is still plentiful rises to the point where hydrogen burning becomes possible. At about 10 million degrees, a hydrogen-fusing shell ignites at the edge of the core and begins to propagate upward through the outer layers of the star like some super-scale brush fire. The energy put out by the moving hydrogen shell now supplies some of the radiation that's emitted from the surface of the star.

Meanwhile back in the core, conditions are getting distinctly tropical. Gravitational contraction has pushed the temperature up to around 100 million degrees and set the scene for — helium flash! Suddenly the core is alive again with fusion reactions. Helium nuclei smash together to form the heavier elements carbon and oxygen. Helium burns and its carbon-oxygen ashes are dumped into the now slightly-expanded core.

But helium is a poorer source of energy than hydrogen. What's more, at the much higher core temperatures needed to fuse it, the reactions proceed faster and the helium supply is exhausted within a few million years. The core again becomes dormant. A second shell, this time burning helium, fires up at the edge of the hot carbon-oxygen core and follows in the path of the still outward-moving hydrogen shell.

Now we're approaching a critical period in the evolution of a star like the Sun. The star's cool, distended envelope is held only tenuously to the hot, inert core. Furthermore, the material of the envelope is in a tremendously dynamic state, its fate lying in the hands of two powerful physical processes: convection and pulsation.

Convection — "boiling" — is a vital heat transfer mechanism in the atmospheres of both red giants and relatively low-mass, main-sequence stars. In a red giant, it may become violent enough to hurl great tongues of matter into a thick shell of gas and dust around the star.

Pulsation, on the other hand, can contribute to an even more dramatic ejection of matter. Its physical origin, distinctly different from that of convection, is connected with the alternate ionization and recombination of hydrogen and helium in the star's distended atmosphere. Basically what happens is that recombining electrons and ions give off energy that heats the outermost layers of the star. These layers then expand, cool, and subsequently fall back again like some giant lung breathing in and out. During their infall, they reheat and re-ionize the underlying ionization zone and the process repeats.

This kind of dynamical ionization instability may be what drives pulsation in the long-period Mira-type variables (which have periods of approximately one year) and also in semi-regular variables like Betelgeuse. But here again remember that the physics of red giants is complex and not at all well understood.

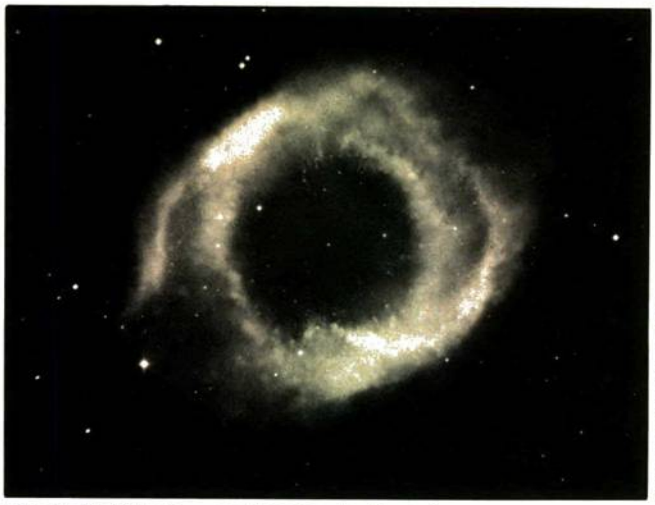
In about 5 billion years, the Sun may have advanced to the semi-regular, pulsating variable stage. It would be very interesting to watch its subsequent evolution from an observation post on, say, Mars. (Earth would be a little uncomfortable by then, with the Sun's seething outer atmosphere only 40 million miles away!)

Our Mars-based astronomers would, over quite a long period (perhaps millions of years), see the Sun's luminosity and radius grow along with the amplitude of its semi-regular pulsations. Let's hope the astronomers are well protected, for at some point the pulsations are likely to get out of control and permanently eject all, or a major portion, of the Sun's tenuous outer layers into space. If their instruments survive the effects of the outward rushing solar envelope, those scientists would witness the birth of one of nature's most beautiful structures: a planetary nebula.

From our vantage point in the Galaxy today, we have identified about 1,000 such "planetaries." This may not seem like many in a system that contains several hundred billion stars, but the planetary nebula stage is very short-lived: it lasts only about 100,000 years before the nebular material thins out to the point of invisibility. The fact that even a thousand of these relatively transient objects have been found indicates that many (if not all) stars having about 1 to 4 solar masses go through this stage.

From detailed observations of planetaries, it's clear that they are expanding away from their parent stars at speeds ranging from 20 to 50 kilometers per second. The nebular material carries with it a high proportion — possibly all — of the old red giant's remaining stock of hydrogen and helium. What's left behind is a very hot, useless ball of carbon and oxygen covered perhaps by a thin mantle of helium.

Mass loss in the form of a planetary nebula ejection, then, marks a dramatic but apparently common step in the evolution of low to intermediate-mass stars. In terms of the Hertzsprung-Russell diagram, it causes a star to jump almost instantly from the tip of the red giant branch to the start of a cooling track that leads to the white dwarf region.


Palomar Observatory photo

The Helix Nebula — a planetary in Aquarius

The central stars of planetary nebulae are among the hottest known. Their surface temperatures can range anywhere from 30,000 K to 100,000 K. And, very importantly for our observation purposes, they fry their cast-off outer envelopes in a blistering bath of high-energy ultraviolet radiation. The expanding circumstellar nebula is ionized under the barrage of ultraviolet radiation and shines at a number of characteristic frequencies as its various ions recombine with stripped electrons.

How much mass is lost in a planetary nebula ejection? The answer seems to depend largely on the individual star; both theoretical and observational results suggest a very broad range. In a recent observational study, M. Perinotto of the Arcetri Observatory derived masses for 43 planetary nebulae ranging from less than $\frac{1}{1,000}$ solar mass to over 10 solar masses! Although the average of Perinotto's planetaries, a fifth of a solar mass, falls reassuringly close to theoretical estimates, it's hard to reconcile the 10,000 to 1 range with any simple picture of ejection.

To understand exactly how the nebular envelope evolves, how its shape and structure unfolds, we must answer a number of questions. What's the precise mechanism of mass loss? Is the nebula ejected violently or more progressively — perhaps by a stellar wind — over thousands of years? Is mass loss uniform or does it come from specific regions of the parent star? How do events following the ejection — evolution of the central star, internal dynamics of the nebular gas, interaction with the interstellar medium — affect the expanding envelope? Unfortunately, we can't turn the clock back 20,000 years to see how the majestic spiral or fascinating comet-like streaks of the Helix Nebula formed. Nor can we travel back to when the embryonic Dumbbell, Ring, or Eskimo Nebulae first began to diverge so markedly in appearance.

Yet it's clear, for all their puzzling differences, that certain objects belong to the common genus "planetary nebula." They share a number of important basic characteristics and we can be pretty confident that they're linked by a common evolutionary path. Some objects, however, masquerade as planetaries but on closer inspection suggest a totally different origin while others share few similarities other than the mere presence of ejected circumstellar material.

In the final part of this two-part article, we'll take a look at what happens when really big stars reach the end of their lives — and the catastrophic aftermath.

David Darling holds a Ph.D. in astronomy and is a computer consultant and freelance writer. His last ASTRONOMY article was "Spectral Visions" in the August and September 1984 issues.

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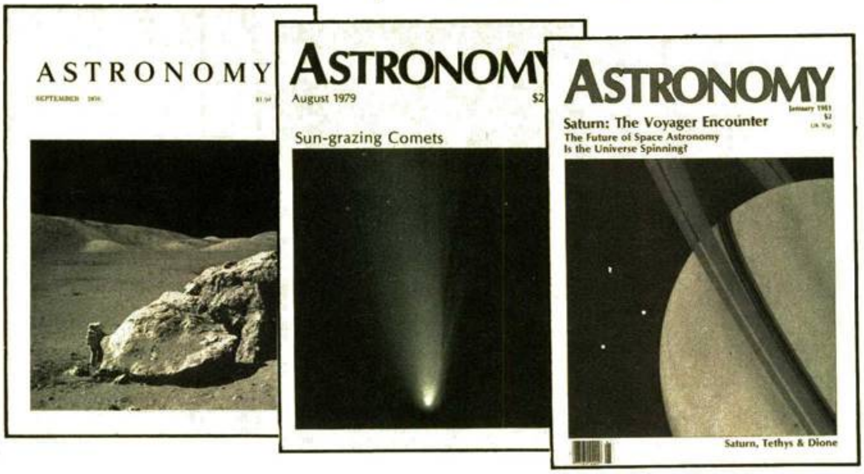
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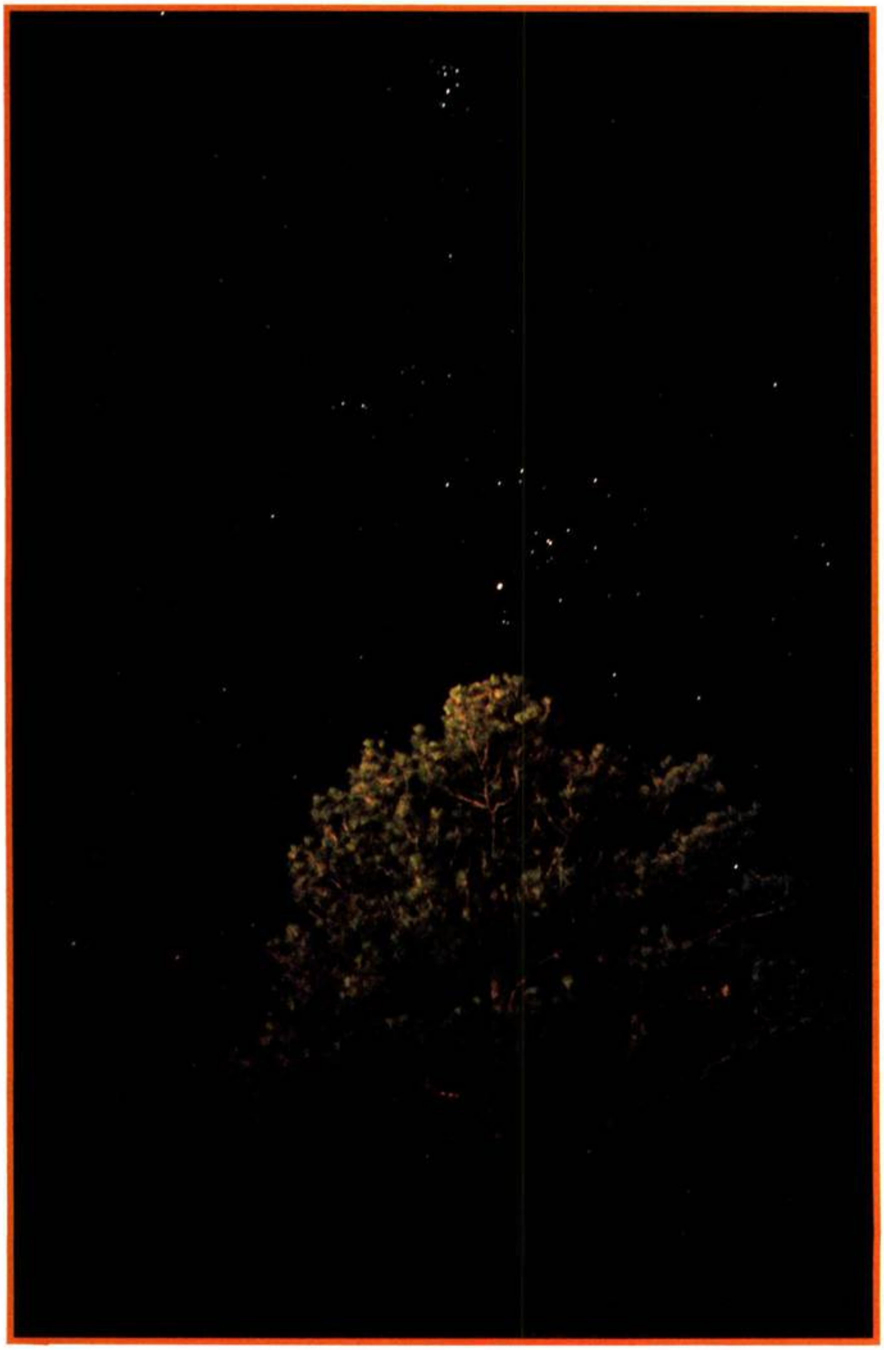
Gazer's Gazette

Discover the Hyades!

by Gail O. Clark



The Triangular Spoon.
The Little Pigs.
The Golden Bull.
The Boiling Sea.

Over the centuries, skygazers have used these colorful names to describe a large, bright star cluster visible during late fall and winter. Although the names appear to have little in common, each represents an impression of the Hyades Cluster — one of the nearest and largest groups of stars in the sky.

Located in the constellation Taurus the Bull, the Hyades is a prime attraction from our vantage point on Earth: while most star clusters lie hundreds or thousands of light-years away, the Hyades is roughly 150 light-years distant. (A light-year is about 6 trillion miles.) The gleaming assemblage of nearby stars is not only a favorite laboratory for astronomers, but also holds the well-deserved reputation as a popular target for telescope and binocular users. (The latter is probably the best instrument to view them with.)

The Hyades is a loose v-shaped group containing about 130 stars brighter than ninth magnitude and several hundred fainter members in an area some 6° across. Such groups are called open, or galactic, clusters because many are found near the Milky Way. The brightest star, Aldebaran (Alpha [α] Tauri), is *not* a member of the group — it's only 60 light-years away — but appears so simply by chance alignment. The brightest star in the Hyades is actually Theta^2 (θ^2) Tauri — a magnitude 3.4, bluish-white, spectral type A7 giant. If all the group's members were compressed into a point, the total magnitude would be a whopping 0.5 —

As winter draws near, the Hyades Cluster — accompanied by bright Aldebaran, which is not a physical member — is a familiar sight rising in the morning sky shortly after the Pleiades. The Hyades is one of the closest star clusters and offers much for binocular and small telescope users. Photo by Gary Karch.

about as bright as Betelgeuse in Orion the Hunter.

The brightest stars in the Hyades are about 150 light-years distant. Many of these stars are very bright, shining at magnitudes 4 and 5. (The Sun, viewed from the Hyades, would appear as a feeble star of magnitude 7.7.) The cluster's distance doesn't even hint at its actual size: the brightest stars compose a stellar community stretching across a vast expanse measuring over seven light-years from edge to edge.

From our perspective, the individual stars in the Hyades appear as if they're converging toward a point in the heavens much like railroad tracks seem to merge at a single point in the distance. Relative to the Sun, the entire system, both bright and dim members, is moving through space at 26 miles per second toward an area of sky near Betelgeuse in Orion. The cluster's motion goes unnoticed during the brief span of a human lifetime, but after many millennia the sparkling stars of the Hyades will shift apart from each other and no longer form a recognizable cluster.

Unlike the neighboring Pleiades, a comparative youngster in the family of galactic clusters, the Hyades has no apparent nebulosity and is devoid of very hot stars. It is about 400 million years old; the Pleiades is only 78 million years old. The Hyades' stars are more than a hundred times older than the stars imbedded in the Great Nebula of Orion, but only a tenth the age of the Sun (and Earth).

As well as being a valuable laboratory for astrophysicists — because of its close proximity — the Hyades Cluster has a background rich in history and mythology. A significant degree of the Hyades' fame is due to its identification with the bull, an animal long popular in ancient Greece whose likeness appeared on coins, urns, statues, and other artifacts. Many cultures held a similar affinity for the male bovine: Egyptian tombs have drawings of the horned creature on their walls and ancient Sumerians also associated the bull with a type of mystical, divine power. And even in the last ice age, the Lascaux cave paintings of France show that early man was fascinated with the animal.

The Brightest Stars

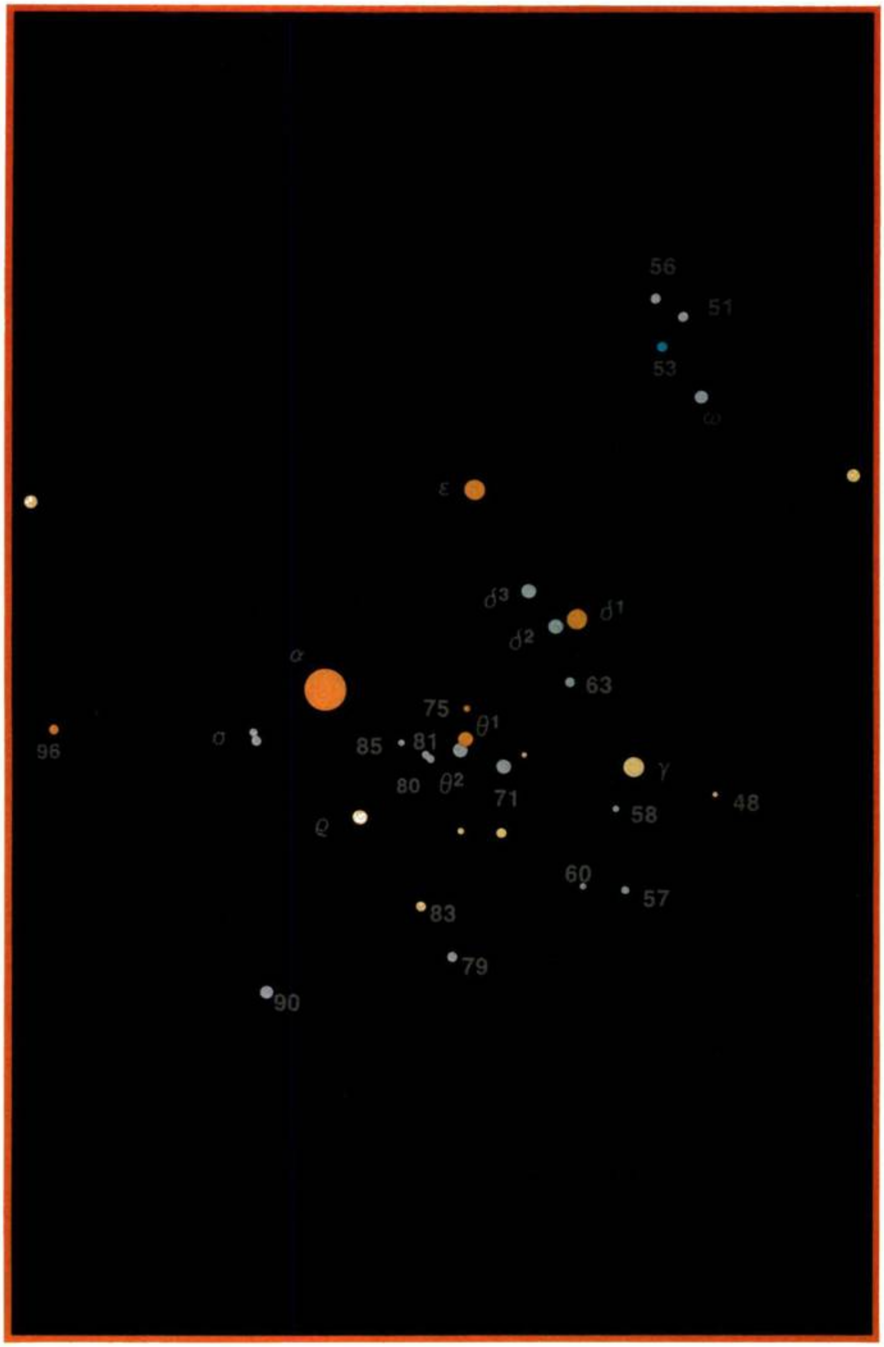
Star	Magnitude	Spectrum
θ^2	3.34	A7 III
ε	3.53	K0 III
γ	3.68	G9 III
δ^1	3.77	K0 III
θ^1	3.87	K0 III
90	4.22	A5 V
δ^3	4.24	A2 IV
71	4.43	F0 V
σ^2	4.59	A5 V
ϱ	4.66	F0 V
δ^2	4.72	A7 V
79	4.93	A6
58	5.17	A8
81	5.40	A7
57	5.49	A9
80	5.50	A6

A persistent allusion to water also surrounds the Hyades Cluster, associating it with damp and rainy weather. An ancient Chinese poet wrote, "The moon is caught in the Hyades; there will be great rains." In Tennyson's *Ulysses*, more recent mention is made: "Thro' scudding drifts the rainy Hyades the moist daughters." The individual stars of the Hyades have also been referred to as nymphs, although none were given individual names as were the stars of the Pleiades.

Suburban Roman landholders labeled the Hyades "The Little Pigs," but left no explanation for this association with swine. The Roman historian Pliny surmised that because roads were sticky with mud when the Hyades set, the elegant star cluster appeared to be wallowing in the wet soil — much like earthly porkers.

The variety of images evoked by the faraway Hyades Star Cluster seems endless. On the next clear evening, why not step outside and discover its enduring charm?

Gail O. Clark is an experienced deep-sky observer and author. He is book review editor for the Reflector, *the Astronomical League's newsletter. His last article in* ASTRONOMY, *"Ancients of the Universe: Globular Clusters," appeared in the May 1985 issue.*



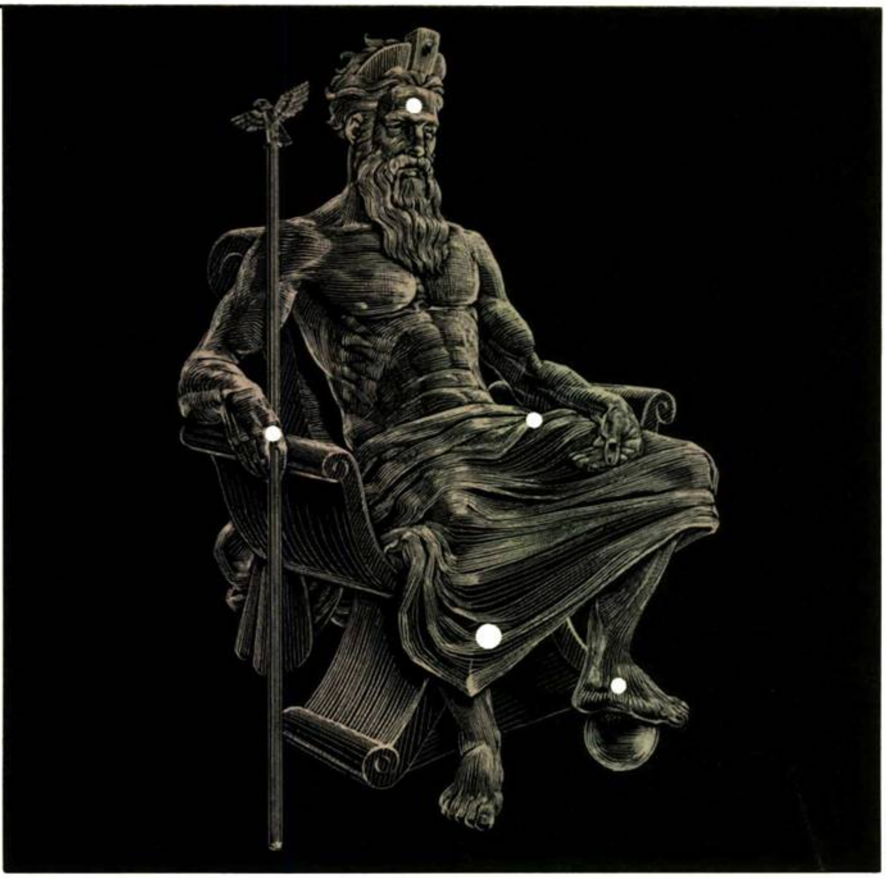
Above: The faint emission nebula IC 1396 is a difficult target for backyard scopes — its light is spread over a diameter measuring nearly 3°. Photo by Ronald Royer. Far left: Although millions of parsecs apart, star cluster NGC-6939 and galaxy NGC-6946 are apparent neighbors lying in the same low-power field of view. Photo by Jack Marling. Top left: The cluster NGC-7510 is bright and easy to spot in binoculars. Photo by Lee C. Coombs. Bottom left: Planetary nebula NGC-40 requires high power to distinguish it from background stars. Photo by Bill Iburg.

Cepheus

Cep
Cephei

Lacerta

Lac
Lacertae



Keith Ward

Lying northeast of the brilliant Milky Way in Cygnus, the constellations **Cepheus** the King and **Lacerta** the Lizard offer numerous clusters and nebulae — and even a strange active galaxy — for backyard telescopes.

The largest object in Cepheus is a region of emission nebulosity catalogued as **IC 1396**, which covers nearly six square degrees of sky. Although first observed by E.E. Barnard with a 6-inch refractor, this faint cloud of nebulosity is normally difficult to spot with small telescopes. The nebula's total light is great, but so spread out that IC 1396 appears little more than a brightening in the Milky Way. Be sure to use a low-power eyepiece when hunting this nebula.

Just at the northern tip of IC 1396 is the unusual ruddy star **Mu** (*μ*) **Cephei**, often called "Herschel's Garnet Star." Mu Cep is the reddest star visible to the naked eye in the northern hemisphere, appearing distinctly deep orange or red to most observers. It is a red giant star which varies in light output semi-regularly, making it fun to follow from week to week. The magnitude range is about 3.7 to 5.0, and its approximate period is about 755 days. (Astronomers have identified additional possibly overlapping periods of 700, 900, 1100, and 4,500 days.)

Mu Cep may well vary in color as well as brilliance. Observers have occasionally mentioned seeing a peculiar purple tint. Others have seen it as deep orange or yellowish orange, while still others find it golden yellow. When you observe Mu Cep, compare it to a known white star in the area, such as Alpha (*α*) Cephei.

Lying to the southeast of Mu is **Delta** (*δ*) **Cephei**, another unusual star. This is the prototypical Cepheid variable — a class of stars which has contributed enormously to our understanding of the universe. First noticed by English astronomer John Goodricke in 1784, Delta Cep's variations have been meticulously recorded for 200 years. The star is a supergiant, and varies between magnitudes 3.6 and 4.3 in about 5.4 days.

Between Delta Cep and the bright star cluster M-52 in Cassiopeia are two unusual objects — NGC-7510 and IC 1470. **NGC-7510** is a bright, compact open star cluster made up of some 60 stars fainter than magnitude 9.7. Spanning only 4′ across, the group appears as a tiny diamond-studded haze in finderscopes and small telescopes, but becomes a fully-resolved cluster in 6-inch scopes. NGC-7510's total brightness is 7.9, making it easy to locate as a myriad of mostly white and bluish-white stars. **IC 1470**, a couple of low-power telescope fields to the southwest, is a tiny emission nebula bathed in an optically-invisible molecular cloud. It measures 70″ x 45″ across and is embedded with a 12th magnitude star which is visible in most telescopes.

NGC-7762 is a fine open star cluster lying in east-central Cepheus. Containing 40 stars, the brightest of which shine at 11th magnitude, this cluster is easily visible in any telescope as a sparse congregation of white and bluish-white stars some 11′ in diameter. Use a low-power eyepiece when first observing this cluster to note the colorful stars filling the area. Then substitute a higher power eyepiece and "zoom in" on individual stars for close inspection.

Farther north in Cepheus is the planetary nebula **NGC-40**, a bright bluish-green disk easily distinguishable from field stars at medium or high power. About 40″ across and with a photographic magnitude of 10.7, NGC-40 is one of the finest of a number of planetaries at high declinations. A 4-inch telescope at 100x shows it as a fuzzy "star," while an 8-incher at 100x clearly reveals its nebular character. At magnitude 11.6, the nebula's central star is easily spied using most telescopes.

Continuing on a wide arc from M-52 in Cassiopeia to NGC-7762 and through NGC-40, we come to the old open cluster **NGC-188** way up near the north celestial pole. Having carefully studied NGC-188's color-magnitude diagram, astronomers believe it is an astonishing five *billion* years old — immensely ancient for an open star cluster. Of the well-studied clusters, only NGC-6791 in Lyra and Melotte 66 in Puppis appear older.

In the eyepiece, NGC-188 is a fairly rich group of 120 stars of magnitude 12 and fainter packed into 14′. Many of its stars are so faint that small scopes show NGC-188 as an unresolved haze; a 6-incher at high power partially resolves the group but still provides the impression of nebulosity. In the largest backyard telescopes, this cluster is a dazzling sight with dozens of faint stars forming unending chains.

For information on naked-eye sky viewing, including planets, constellations, and mythology, see **Eye on the Sky**.

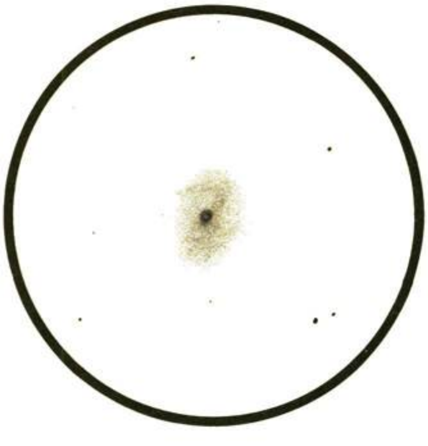
Farther south, back in the west-central part of Cepheus, is the faint reflection nebula **NGC-7023**. As are most reflection nebulae, this is a difficult object to observe because it is fairly large and diffuse. Measuring 18′ across and dimly lit by a seventh-magnitude type B5e star, NGC-7023 demands a 6-inch telescope for viewing even under dark skies. With a 10-inch or larger scope, the nebulosity is fairly easy to see but appears completely featureless.

A galaxy and an open cluster — both in the same low-power field but separated in space by five megaparsecs — lie near the far western part of Cepheus. **NGC-6939** contains 80 stars in an area spanning a mere 8′ across, making it one of the richest, most stunning open clusters in the area. Its brightest stars shine slightly brighter than 12th magnitude, giving it the overall glow of an eighth-magnitude star. It is easily visible in finderscopes and a fine object in any telescope. Large scopes at high power provide a field absolutely packed with stars. Nearby is the galaxy **NGC-6946**; at five megaparsecs' distance, it is one of the nearer galaxies outside the Local Group. It is face-on to our line of sight and appears as a tight, bright core surrounded by a faint haze representing its spiral arms. Large backyard scopes show a mottled structure in the haze, suggesting patches of dark dust.

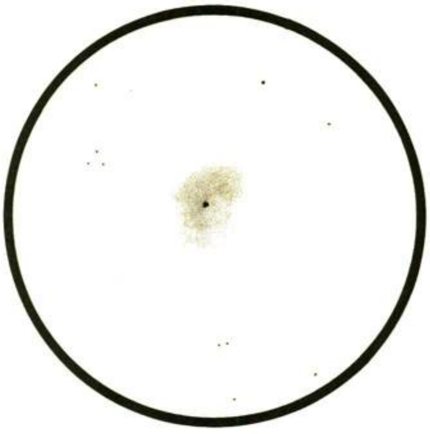
The planetary nebula **NGC-7139** in the central part of Cepheus is large but dim. Measuring over one arc-minute across, it is large enough to avoid confusion with surrounding stars. Its photographic magnitude of about 13 leads you to expect a very low surface brightness. Nonetheless, a 12-inch scope at high power shows it as a smooth fuzzy disk devoid of a central star.

Much smaller and sandwiched between bright Cygnus and Cassiopeia, Lacerta contains several clusters, a planetary nebula, and a strange galaxy-like object. The clusters — **NGC-7209**, **NGC-7243**, and **NGC-7245** — are large and bright. NGC-7209 shines at seventh magnitude and measures a full Moon diameter across, making it obvious in binoculars. NGC-7243 is only slightly smaller and a bit brighter, so that it too is best observed with a wide field. NGC-7245, on the other hand, is 5′ across, shines at ninth magnitude, and contains only a handful of stars.

NGC-6946 8-inch f/10 SCT 50x



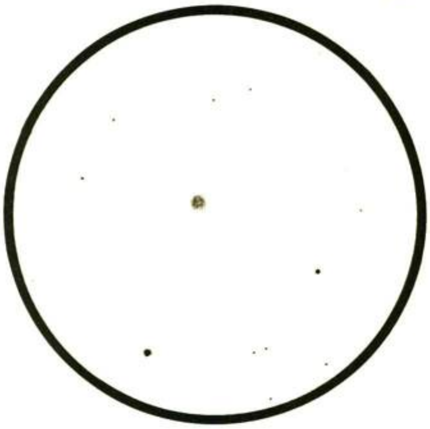
NGC-7023 8-inch f/10 SCT 50x



The tiny planetary nebula **IC 5217** is a difficult object to identify against the rich Milky Way in Lacerta. It is practically stellar — 6″ across — and glows at magnitude 12.6. Its bluish color may help give it away; try finding the appropriate area and using high power on "suspect" stars.

The most bizarre object in the area is **BL Lacertae** — originally thought to be a variable star. A detailed look at its spectrum, however, erased such notions — it is an unusual variable galactic nucleus, throwing off high energy radiation much like a quasar. BL Lac is faint — it varies by half a magnitude from 14.7 — and star-like, but if you observe it you'll be seeing a high-energy active galaxy some 270 megaparsecs away.

NGC-7139 8-inch f/10 SCT 50x

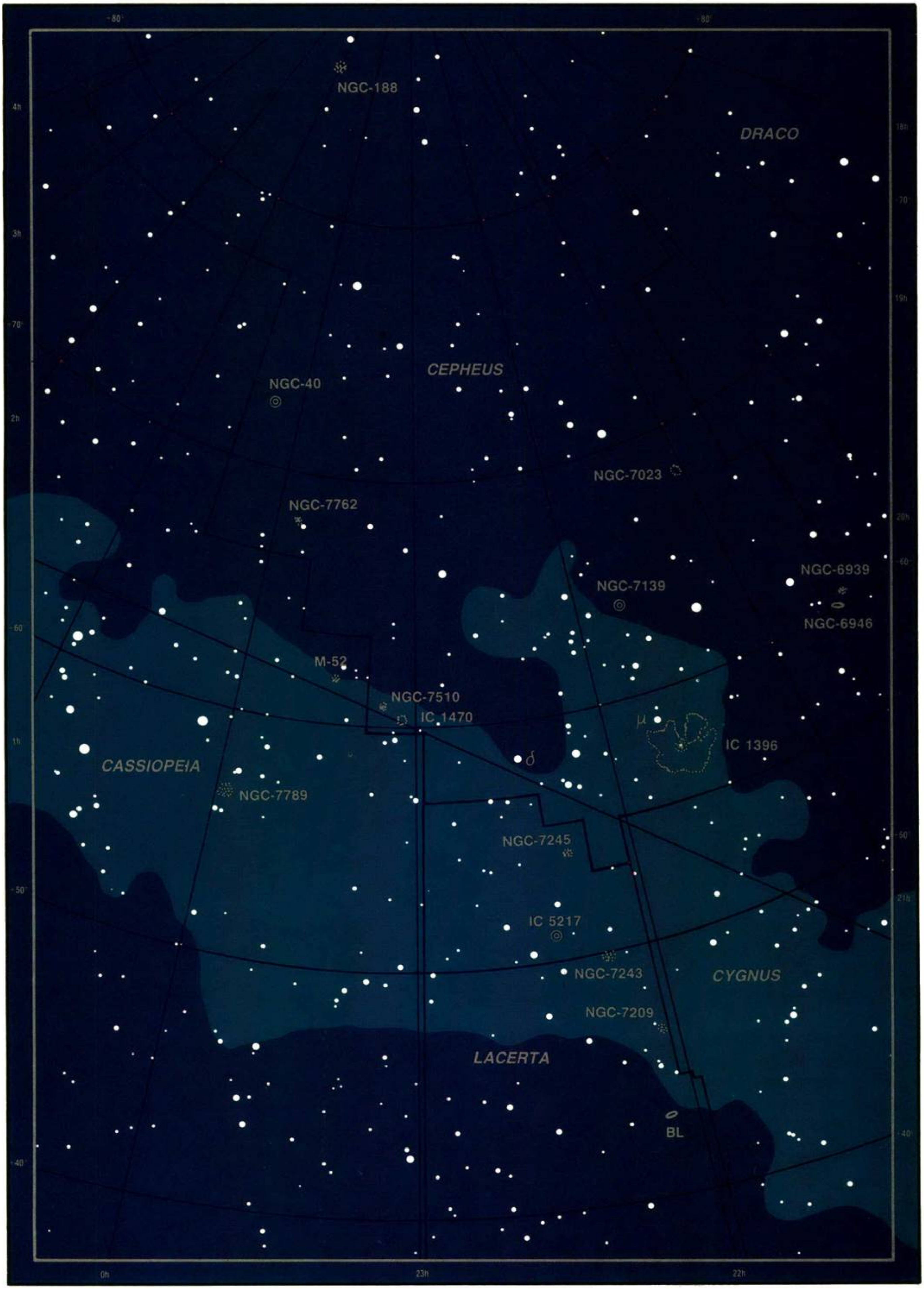


Sketches by David J. Eicher

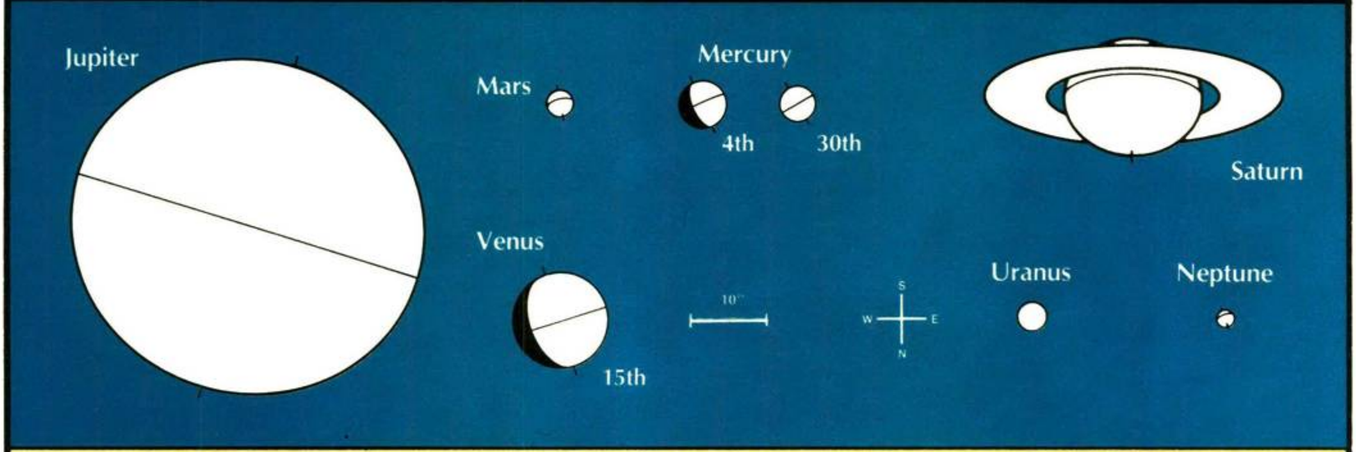
Object	M#	Type	R.A. (2000)	Dec.	Mag.	Size/Sep./Per.	N★
NGC-40		■	0h 13.0m	+72°32′	10.7p	40″	
NGC-188		⊙	0h 44.4m	+85°20′	8.1	14′	120
NGC-6939		⊙	20h 31.4m	+60°38′	7.8	8′	80
NGC-6946		§	20h 34.8m	+60°09′	8.9	11.0′ x 9.8′	
NGC-7023		☐R	21h 01.8m	+68°12′	—	18′	
IC 1396		☐E	21h 39.1m	+57°30′	—	170′ x 140′	
NGC-7139		■	21h 45.9m	+63°39′	~13p	78″	
BL Lac		QSO	22h 02.7m	+42°16′	14.7v	stellar	
NGC-7209		⊙	22h 05.2m	+46°30′	6.7	25′	25
NGC-7243		⊙	22h 15.3m	+49°53′	6.4	21′	40
NGC-7245		⊙	22h 15.3m	+54°20′	9.2	5′	3
IC 5217		■	22h 23.9m	+50°58′	12.6p	6″	
IC 1470		☐E	23h 05.2m	+60°15′	—	70″ x 45″	
NGC-7510		⊙	23h 11.5m	+60°34′	7.9	4′	60
NGC-7762		⊙	23h 49.8m	+68°02′	10p	11′	40

N★ = number of stars

⊙	*Open Star Cluster*
■	*Planetary Nebula*
☐E	*Emission Nebula*
☐R	*Reflection Nebula*
§	*Spiral Galaxy*
QSO	*Quasar*

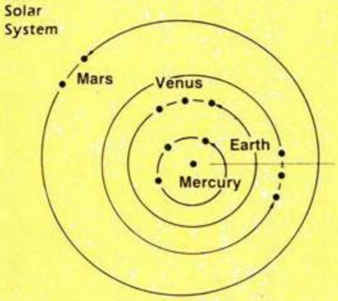

80°
80°
NGC-188
4h
DRACO
18h
70°
3h
19h
70°
CEPHEUS
NGC-40
2h
NGC-7023
NGC-7762
20h
60°
NGC-6939
NGC-7139
NGC-6946
60°
M-52
NGC-7510
IC 1470
μ
1h
IC 1396
δ
CASSIOPEIA
NGC-7789
50°
NGC-7245
50°
21h
IC 5217
NGC-7243
CYGNUS
NGC-7209
LACERTA
BL
40°
40°
0h
23h
22h

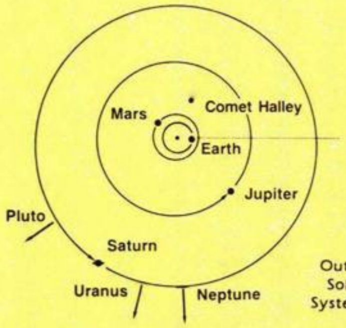
Planetary Data — September 1985


Jupiter
Mars
Mercury
4th
30th
Saturn
Venus
15th
10"
S
W
E
N
Uranus
Neptune

		Date	Mag.	Angular Size	% Illum.	Distance (AU) from: Earth	Sun	Longitude: Heliocentric	Ecliptic	R.A. (2000.0)	Dec.
Sun		1	−26.7	31.8′	—	1.01	—	—	158°30.7′	10h 41.3m	8°18.5′
		15	−26.7	31.9′	—	1.01	—	—	172°06.4′	11h 31.7m	3°03.4′
		30	−26.7	32.0′	—	1.00	—	—	186°47.1′	12h 25.6m	− 2°46.2′
Mercury	☿	1	−0.6	6.6″	59%	1.01	0.31	60°44.5′	141°19.4′	9h 34.6m	14°54.4′
		15	−1.4	5.1″	96%	1.32	0.34	144°16.7′	165°22.0′	11h 08.9m	7°26.6′
		30	−1.1	4.8″	99%	1.41	0.42	205°45.6′	192°33.5′	12h 47.6m	− 4°13.7′
Venus	♀	1	−4.0	13.0″	81%	1.29	0.72	73°10.2′	124°47.2′	8h 28.3m	18°58.0′
		15	−4.0	12.2″	85%	1.37	0.72	95°46.4′	141°35.4′	9h 36.6m	14°52.5′
		30	−4.0	11.6″	89%	1.44	0.72	120°05.3′	159°50.2′	10h 47.2m	8°58.0′
Mars	♂	10	1.8	3.6″	99%	2.59	1.66	139°35.2′	150°10.2′	10h 10.7m	12°31.5′
		20	1.8	3.7″	99%	2.56	1.66	143°58.9′	156°30.3′	10h 34.8m	10°14.4′
Jupiter	♃	15	−2.7	45.8″	100%	4.30	5.07	315°39.4′	307°54.1′	20h 42.1m	−19°09.8′
Saturn	♄	15	0.6	15.9″	100%	10.40	9.96	238°36.1′	233°43.3′	15h 27.3m	−16°48.8′
Uranus	⛢	15	5.6	3.7″	100%	19.21	19.10	257°11.0′	254°26.1′	16h 52.2m	−22°34.3′
Neptune	♆	15	7.9	2.2″	100%	30.08	30.25	272°44.1′	271°04.9′	18h 04.5m	−22°19.2′
Pluto	♇	15	13.8	0.1″	100%	30.47	29.75	214°23.1′	213°16.5′	14h 26.1m	2°41.8′

Inner Solar System


Mars
Venus
Earth
Mercury

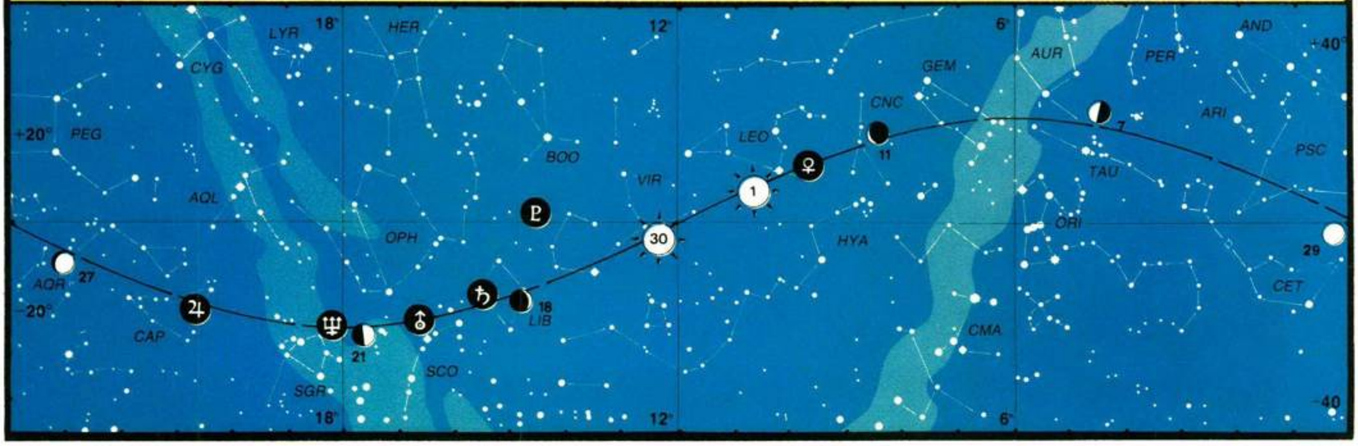

Mars
Comet Halley
Earth
Jupiter
Pluto
Saturn
Uranus
Neptune

Outer Solar System

Moon Data

Last Quarter. . . . . . . September 7 at 12h16m
New Moon. . . . . . September 14 at 19h20m
First Quarter. . . . . September 21 at 11h03m
Full Moon. . . . . September 29 at 0h08m
Last Quarter. . . . . October 7 at 5h04m
New Moon. . . . . October 14 at 4h33m

Apogee: Sept. 4 at 21h02m. . . . 404,792 km.
Perigee: Sept. 16 at 18h44m. . . 362,298 km.


LYR
18h
HER
12h
6h
AUR
AND
+40°
CYG
GEM
PER
CNC
+20°
PEG
ARI
7
LEO
11
PSC
BOO
TAU
AQL
VIR
1
ORI
OPH
30
HYA
29
AQR
27
CET
−20°
18
LIB
CAP
21
CMA
SCO
SGR
18h
12h
6h
−40

On July 9th, a bright aurora was visible over Madison, Wisconsin, where Jeff Peronto photographed it. He used a 15mm f/2.8 fish-eye lens and a 3-minute exposure on 3M 1000 slide film.

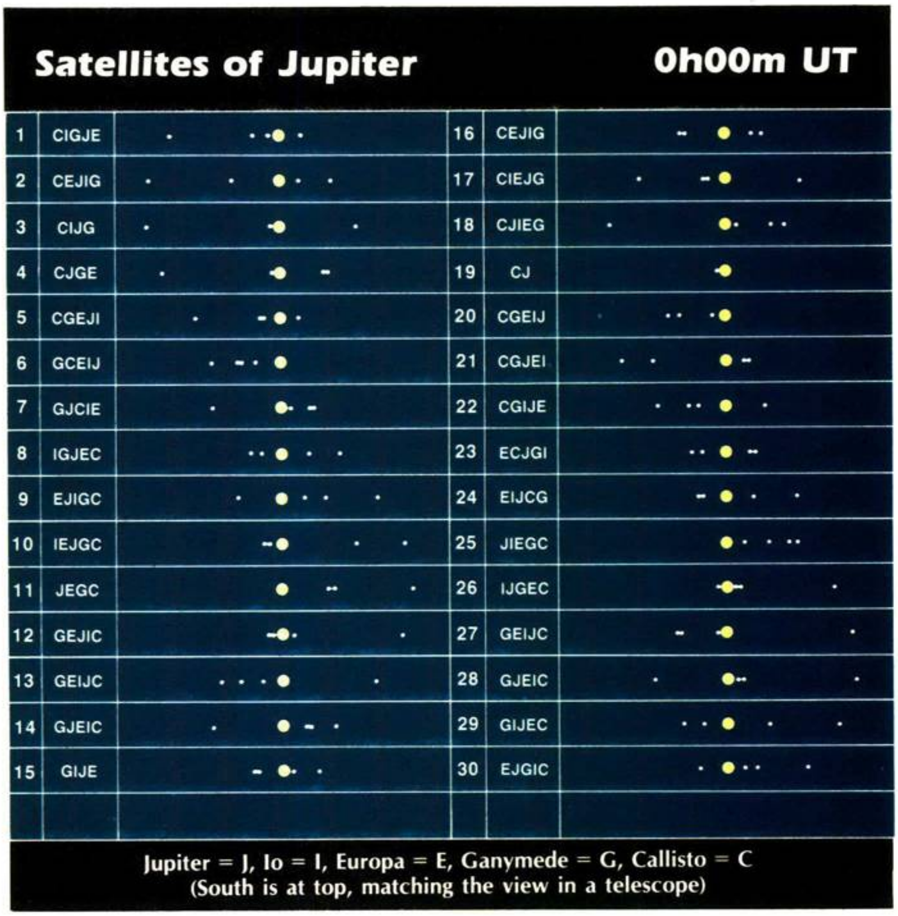
Mercury

Mercury will be visible briefly in the morning sky for the first few days of September, but then sinks too close to the Sun to be seen. Superior conjunction comes on September 22nd.

On the morning of the 4th, look for Mercury very close to Mars. This pairing will be difficult to observe; essentially, you'll need a flat eastern horizon. The two planets will lie near Regulus in Leo. Venus serves as a pointer: scan at low power below and to the left of it. Regulus is at magnitude 1.4, Mercury at −0.8, and Mars at 1.8.

Venus

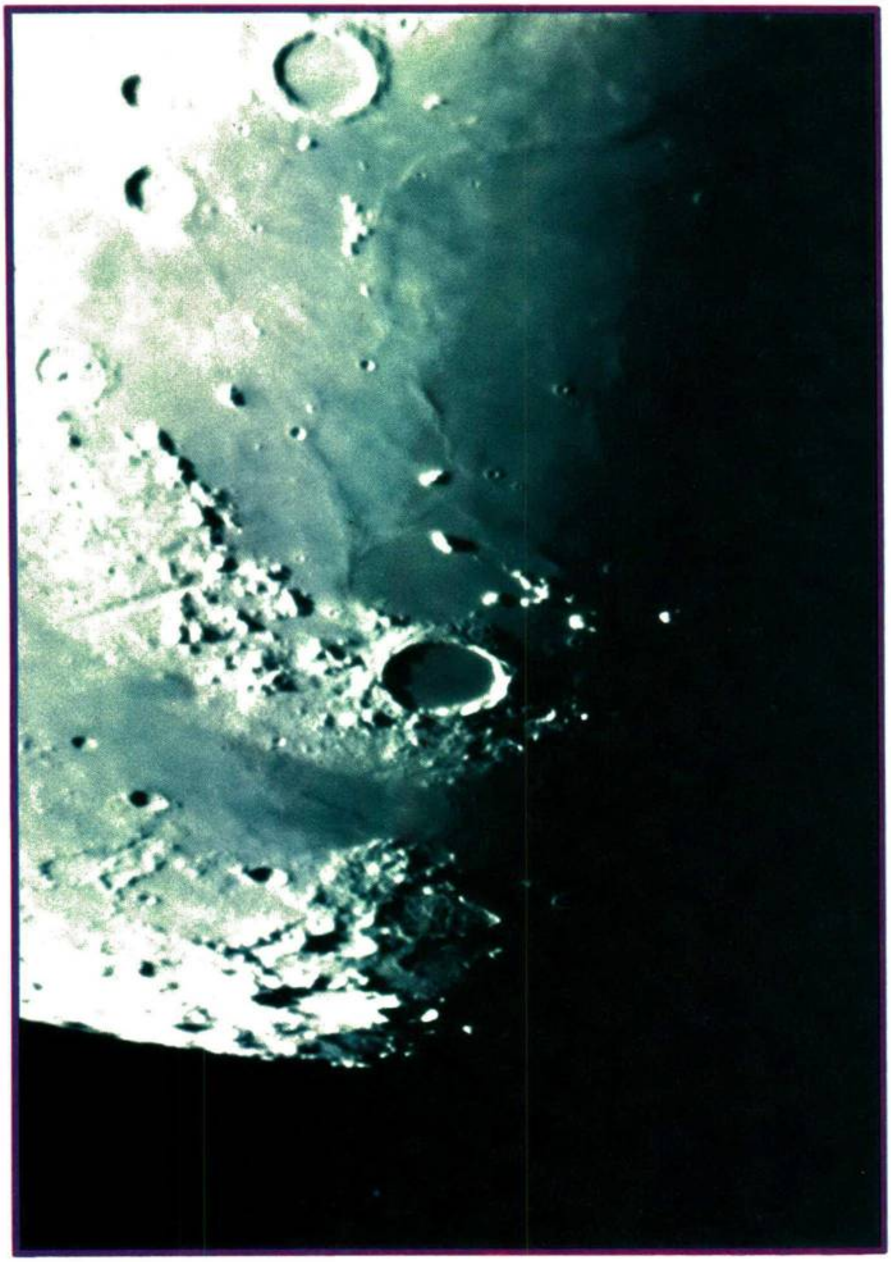
Having "peaked out" in early August, Venus is now on a descending track in the morning sky. With Venus a little lower each morning, you'd do well to start following it into morning twilight. In every telescope, Venus is a blaze of light and most Newtonians show it flanked with big diffraction spikes. Use the twilight to cut the extreme contrast. When the sky is very dark, Venus is too bright (and often too low); conversely, soon after sunrise the sky



Satellites of Jupiter **0h00m UT**

1	CIGJE	16	CEJIG
2	CEJIG	17	CIEJG
3	CIJG	18	CJIEG
4	CJGE	19	CJ
5	CGEJI	20	CGEIJ
6	GCEIJ	21	CGJEI
7	GJCIE	22	CGIJE
8	IGJEC	23	ECJGI
9	EJIGC	24	EIJCG
10	IEJGC	25	JIEGC
11	JEGC	26	IJGEC
12	GEJIC	27	GEIJC
13	GEIJC	28	GJEIC
14	GJEIC	29	GIJEC
15	GIJE	30	EJGIC

Jupiter = J, Io = I, Europa = E, Ganymede = G, Callisto = C
(South is at top, matching the view in a telescope)



Right: September's "Best Astro-Photo" award goes to Preston Justis for his photo of NGC-253, the bright spiral galaxy in Sculptor. He used a 10-inch f/6 Newtonian, a 64-minute exposure, and a 103a-O film. Left: Mare Imbrium, Plato, and the Alpine Valley by Jack Metcalfe (8-inch SCT, f/53, 3 seconds on 2415 film).

becomes too bright. This leaves you about an hour, roughly 30 minutes before sunrise till 30 minutes after, when Venus is at its best.

Earth

At 2h08m UT on the 23rd, the center of the Sun crosses the celestial equator and autumn begins in the northern hemisphere, spring in the southern.

Mars

The Red Planet is a difficult object in the morning sky. You can probably locate it best by sweeping down and to the left of Venus. A small tawny orange ball, Mars lies over 2.5 astronomical units away; as a result, its apparent diameter is but 3.6 seconds of arc.

Minor Planets

1 Ceres (magnitude 8.4) spends part of September in Cancer and part in Leo. Its positions:

10th: 8h 55m 20s, 22° 24.6′
20th: 9h 12m 58s, 21° 37.0′

Ceres rises around 4 a.m. local daylight time on the 15th.

2 Pallas (8.8) is moving southeastward in Orion and Lepus this month. Its positions:

10th: 5h 34m 31s, −10° 00.4′
20th: 5h 47m 39s, −12° 23.6′

Pallas rises about 3 a.m. local daylight time on the 15th.

3 Juno (11.4) lies in Virgo, about 10° north of Spica. Its positions:

10th: 13h 30m 31s, −1° 58.0′
20th: 13h 42m 44s, −3° 05.0′

Juno sets around 8:30 p.m. local daylight time on the 15th.

4 Vesta (7.6) is moving eastward in Libra. It passes 53′ north of Saturn at 17h25m UT on the 16th. Its positions:

10th: 15h 15m 45s, −14° 54.3′
20th: 15h 33m 52s, −16° 28.3′

Vesta sets about 9 p.m. local daylight time on the 15th.

For convenience in plotting their motions on a star atlas, all minor planet positions are for the epoch 2000.0.

Jupiter

A bright object in central Capricornus, Jupiter is easy to spot in the southeastern sky after sunset. It is also a rewarding object for your telescope. Try to set up your scope and observe before twilight ends, since a small measure of skylight helps make details on the planet stand out better. If you can't find Jupiter until the sky is quite dark, note where you see it (relative to trees and houses) and scan a little to the east of that same place, using low power, earlier the next night.

Some good jovian moon events include Io's partial eclipse of Europa (3h15m to 3h29m UT on September 14th), which causes a 1.4-magnitude drop in brightness. (The same two do it again on the 21st between 5h57m and 6h09m UT with a 2.1 magnitude drop.) Both events take place about 3.5 Jupiter diameters east of the planet. On the 25th, Callisto undergoes an annular eclipse by Ganymede between 4h59m and 5h18m UT with a 1.4 magnitude drop in brightness. The eclipse occurs eight Jupiter diameters east of the planet.

Saturn

Saturn is about to vanish into the western twilight. As with Jupiter, try to observe Saturn during twilight. This helps in detecting surface detail and the atmospheric seeing is better, too. Solar conjunction comes in late November, but Saturn will be out of view well before then.

Uranus

In the evening sky this month, Uranus makes a rough equilateral triangle with Antares and Epsilon (ε) Scorpii. (Uranus lies northeast of the two stars.) You'll probably spot the planet in your finderscope, and a glance into the main eyepiece will confirm it. Uranus is a bright greenish (greenish grey in small apertures) disk, 3.7 seconds of arc across.

Neptune

On September 1st, Neptune lies about 10 minutes of arc north of the small open cluster M-21 in Sagittarius. Put in a low-power ocular, center your scope on M-20 (the Trifid Nebula), and sweep about a degree to the northeast. After passing M-21, look for a grey-green dot measuring 2.2 seconds across — that's Neptune.

Comet Halley

To locate Halley, see the map on pages 36 and 37 in last month's issue. The comet is now passing through Orion's upraised club. Its positions (epoch 2000.0):

10th: 6h 11m 27s, 19° 30.1′
20th: 6h 12m 56s, 19° 42.3′

Halley will reach 12th magnitude by mid-September.

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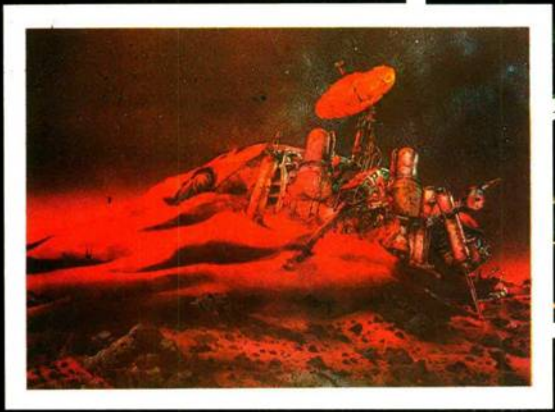

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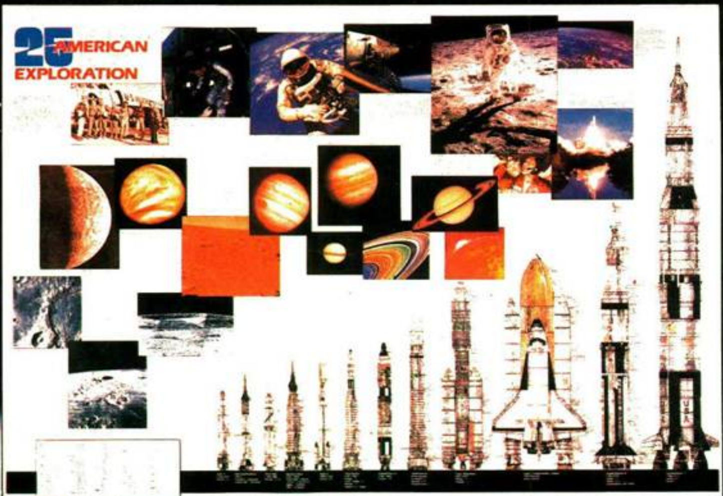
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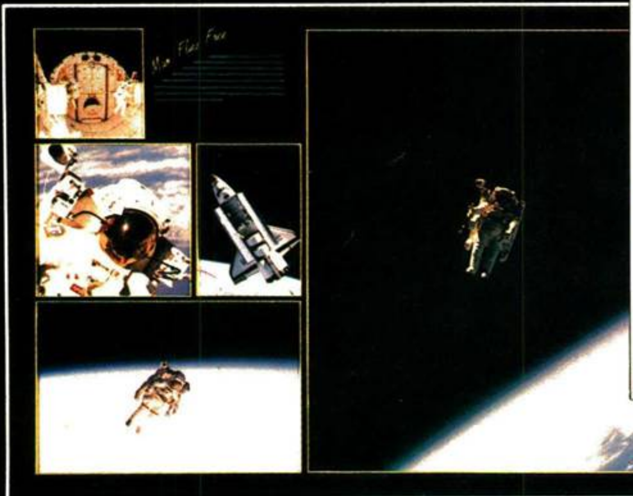
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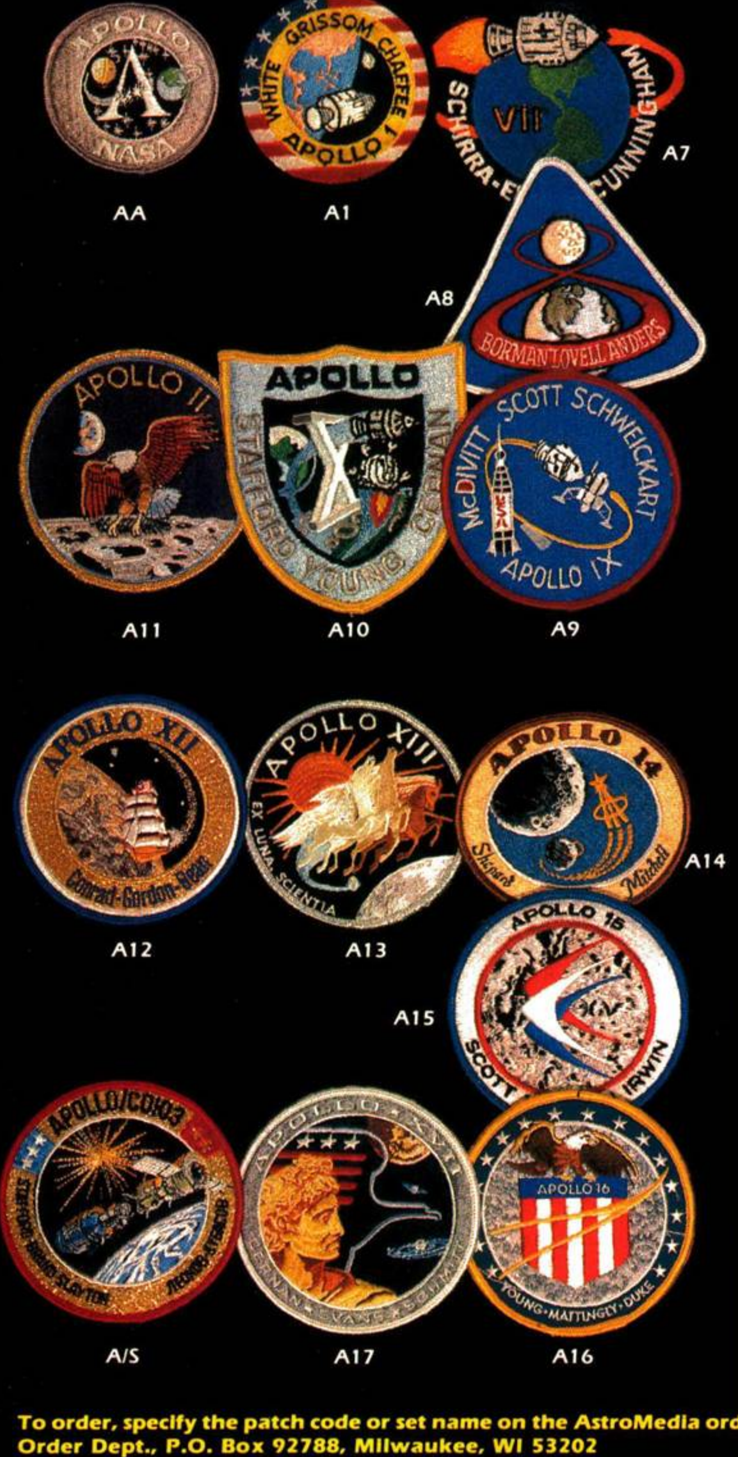
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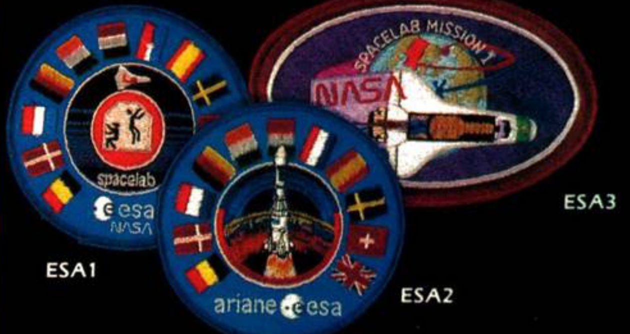
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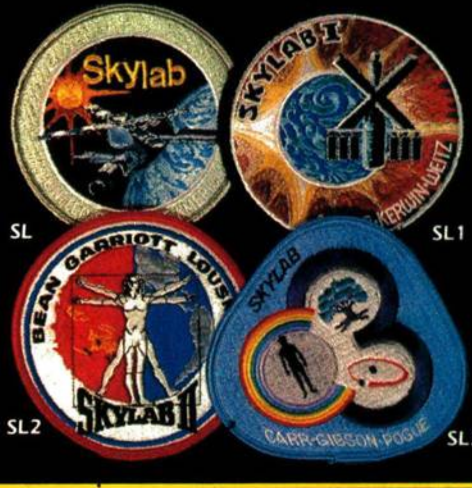
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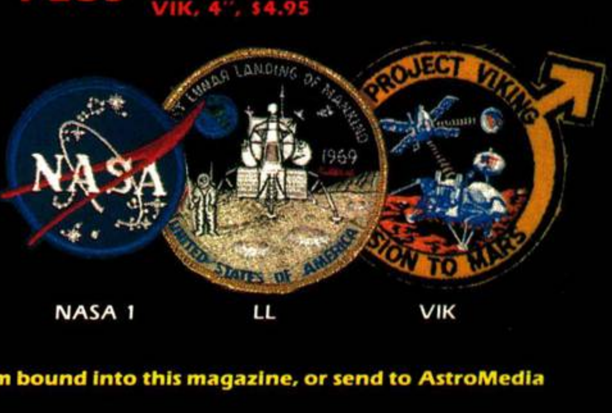
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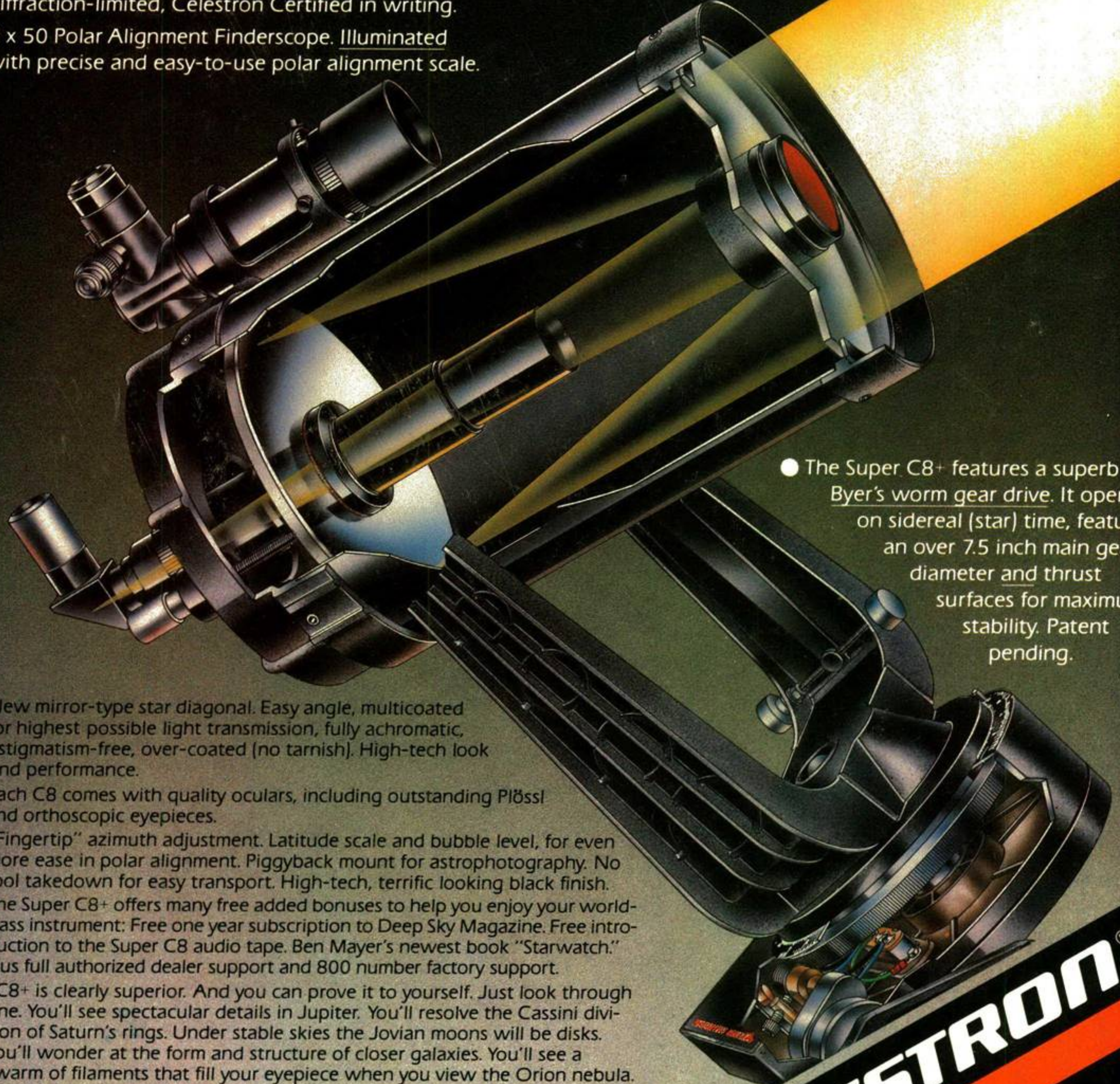

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